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ENGINEERING DESIGN HANDBOOK

MILITARY PYROTECHNICS SERIES
PART TWO—SAFETY, PROCEDURES ANI) GLOSSARY

HEADQUARTERS, U. S. ARMY MATERIEL COMMAND

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(AMCRD)

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PREFACE

This handbook constitutes Part Two of a planned series on Military Pyrotechnics and forms part of the Engineering Design Handbook Series of the Army Materiel Command. Part Two deals with the problems of safety in the pyrotechnics laboratory and plant, processing procedures and equipment, particle size procedures, and contains a glossary of terms.

Part Three, a separate handbook with the same date of publication, contains data sheets on 128 ingredients used in pyrotechnic compositions.

Part One, under preparation at the time of publication of Parts Two and Three, will deal with the physical and chemical theoretical aspects of the production of pyrotechnic effects, and the application of the theory to practice. It will also include a history of the pyrotechnic art and an extensive bibliography.

A future volume, currently in the planning stage, will be devoted to discussion of methods used in the evaluation of pyrotechnic items, determination of their compliance with the requirements of the using services, special equipment and procedures which are followed in tests and evaluation, and considerations affecting the interpretation of results.

Material for Parts Two and Three was prepared by McGraw-Hill Book Company for the Engineering Handbook Office of Duke University, prime contractor to the Army Research Office--Durham. The entire project was under the technical guidance of an interservice committee, with representation from the Army Chemical Center, Ballistics Research Laboratories, Frankford Arsenal, Harry Diamond Laboratories, Picatinny Arsenal, U. S. Naval Ammunition Depot (Crane), U. S. Naval Ordnance Laboratory, and U. S. Naval Ordnance Test Station. Chairman of this committee was Mr. Garry Weingarten of Picatinny Arsenal.

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Comments and suggestions on this handbook are welcome and should be addressed to Army Research Office--Durham, Box CM, Duke Station, Durham, North Carolina 27706.

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CHAPTER 1

SAFETY IN THE PYROTECHNICS LABORATORY AND PLANT

1. INTRODUCTION

This chapter presents the basic principles and considerations involved in achieving safety. It is intended as a guide to help reduce accidents during the research, development, and processing of new and improved military pyrotechnics. The material presented here does not replace existing safety regulations, procedures, Standard Operating Procedures (SOP'S) or bulletins, but is intended to supplement them and to aid in the preparation of new regulations.

Safe practices in handling pyrotechnics are the result of the experiences and knowledge of interested personnel and safety experts. All safety-conscious personnel know the necessity for abiding by established safety rules for their own protection and for the protection of others. The processing, testing, storage, and disposal of pyrotechnic materials and items present problems because many of the ingredients and mixtures are toxic, sensitive, and potentially explosive. A thorough knowledge of pyrotechnic ingredients, compositions, and their reactions is an absolute necessity for handling pyrotechnics in the best and safest manner. A bibliography of pertinent literature is included at the end of this chapter. Safety cannot be delegated; it is the responsibility of each worker. Supervisors must personally assume responsibility for educating subordinates and promoting safety within their groups.

Pyrotechnic compositions are physical mixtures of finely powdered compounds and elements. The main constituents are (1) oxidizing agents such as chlorates, perchlorates, nitrates, peroxides, oxides, and chromates; (2) fuels such as powdered metals, silicon, boron, sulfur, hydrides, and sugar; and (3) binders and color intensifiers, which are usually organic. When ignited, these mixtures readily undergo an exothermal reaction that generates considerable energy in a relatively short period of time. The heat of reaction for one gram of pyrotechnic composition ranges from approximately 200 to 2500 calories per gram. This amount of energy, although dangerous, is generally not as destructive as the energy of explosives because it is released as light and heat, with temperatures ranging from approximately 1000° to 3500 °C, rather than as mechanical energy. Loose flash compositions, even when unconfined, are the exception because (1) they release their energy in a much shorter time than pressed pyrotechnic compositions, although less rapidly than explosives; (2) the volume of air entrapped in the composition increases its brisance; and (3) when confined, there is an additional danger from the high velocity fragments of the ruptured case.

Pyrotechnic ingredients and compositions must also be considered hazardous because of their toxicity and sensitivity. Without prior knowledge, or if physico-chemical principles are inadequate, one must consider new ingredients or compositions potentially hazardous. Each new material and composition must be evaluated to determine toxicity, sensitivity, processing hazards, and optimum methods of storage and disposal. Taking chances and failing to follow specified safety practices are the most frequent causes of accidents in the laboratory or plant.

2. BASIC SAFETY RULES

The safety precautions that apply to pyrotechnics may be summarized in the following four rules:

(1) Know the properties of ingredients and the reactions of compositions.

(2) Recognize the dangerous situations that may arise because of potential or actual hazards.

(3) Minimize the hazards by working with small samples, and observing established practices for safety equipment, processing, testing, storing, and disposal.

(4) Observe the practices of good housekeeping.

These rules are interdependent, and inattention to one defeats the objectives of the others. To minimize a hazardous situation the conditions that are or can be dangerous must be recognized; this requires a thorough understanding of the characteristics and properties of pyrotechnic ingredients and the practices and procedures that constitute safe housekeeping.

a. Knowledge of Pyrotechnic Materials

No experiment or mixture preparation should be undertaken without thorough knowledge of the properties of the ingredients to be used and the reaction products that result from testing. The literature should be consulted for toxicity, sensitivity, compatibility, storage, and disposal precautions. Before any experiment or preparation is started, each supervisor should make certain his subordinates comprehend fully, and are using, the best and safest practices.

A knowledge of pyrotechnic materials will depend on understanding the following six important characteristics:

(1) Toxicity

(2) Sensitivity

(3) Reactions with other materials

(4) Safe working limits

(5) Storage characteristics

(6) Disposal precautions

The first four points are discussed immediately below. Storage and disposal are discussed under Processing Pyrotechnic Materials.

(1) Toxicity. If toxicity is defined as the inherent ability of a chemical substance to produce injury once it gains access to the body and hazard, as the likelihood of toxic injury occurring while handling or using a chemical, one can see that a chemical of high toxicity is not necessarily a hazard. Under the usual circumstances of handling or use the likelihood of toxic exposure may not arise; whereas, a chemical of low toxicity may be extremely hazardous if handling provides opportunity for toxic exposure.

A chemical must be considered toxic if it injures tissues or organs so as to prevent them from functioning normally. All possible exposures and effects must be considered. In general, chemical injury results from skin contact, ingestion, and inhalation. The eyes may be injured and vision impaired; skin may be irritated, blistered, or burned in such a manner that a permanent scar may be formed. Swallowing may result in irritation or injury to the digestive tract. Inhalation of toxic dusts, vapors, or smokes may result in irritation or permanent injury to the nasal passages and lungs. The degree of injury from contact varies greatly; it may be slight or serious, and may occur rapidly or may be delayed for days, weeks, or years. To produce injury to internal organs, a toxic substance must enter the blood stream through the lungs, the mouth, or the skin (either percutaneously or through an open break).

Avoidance or prevention of toxic exposures may take forms such as the use of protective clothing and equipment, ventilation of buildings, proper design of equipment, and proper storage of toxic chemicals. Thus, all those concerned (supervisors, safety officers, engineers, and operators) must make a concerted effort to reduce hazards. All personnel handling chemicals should know possible hazards, control, and first aid treatment. The extent of prevention procedures must be determined by the possibility of exposure under the conditions of use, by the toxicity of the chemical, by the nature of its effects in or on the body, and by the way in which it gains access to the body.

The health hazard normally associated with handling pyrotechnic items, aside from skin contact, ingestion, and inhalation of the components during manufacture, is the inhalation of the end products after dissemination. All ingredients used in pyrotechnics should be considered potentially toxic; this also applies to compositions and the products of reaction. All possible precautions should be taken to minimize exposure to dusts and vapors generated during handling and testing.

Each compound must be treated as a potential health hazard until all exposure limits have been established for man, on an acute and chronic basis. Personnel who come in contact with pyrotechnic materials should use protective clothing, masks, goggles, and skin creams, and practice personal cleanliness to avoid toxic complications. Safety experts and medical authorities should be notified immediately on any question about exposure to toxic materials or any unusual symptoms after exposure. Labels on stored materials should indicate the tpxicity of the material and the antidote or treatmentif kiiown.

(2) Sensitivity. The sensitivity of a pyrotechnic composition is considered as its response to external stimuli such as heat, impact, friction, moisture, electrostatic discharge, and initiation. In this section these tests are briefly described. A full description of the testing procedure appears in the section on Evaluation Tests. No full scale preparation of a new or experimental mixture should be undertaken without conducting sensitivity tests on small specially prepared samples. Full scale preparation may be attempted only if the results of the sensitivity tests indicate that no definite or potential hazard exists. If an uncertainty exists, the preparation should be scaled up in minimum increments to gain experience before attempting a full scale preparation. It should be noted that sensitivity tests do not always give a definite correlation with actual practice, because the physical conditions involved in laboratory or plant preparations seldom duplicate the controlled conditions in laboratory sensitivity testing. Experience has shown, however, that sensitivity tests are reliable guides for categorizing compositions with respect to sensitivity.

(a) Sensitivity to heat. Because all pyrotechnic compositions are initiated by heat or heat plus shock, one should use some of the common tests to establish or measure the response of an ingredient or a composition when exposed to heat.

Ignition temperature. This is most often done by placing a small quantity of the material in a thin walled metallic container such as a copper blasting cap, and inserting the cap and its contents rapidly into a molten metal bath of known and controlled temperature. This process is repeated at various selected temperatures, and the time from insertion to reaction is noted. The average time for each temperature is plotted against the reciprocal of the absolute temperature. The slope of the line is calculated in the Arrhenius fashion to yield the activation energy of the sample. This value can be taken as a measure of the sensitivity to heat of the sample. /16/

Autoignition temperature. Another test for sensitivity to heat is maintaining the sample at a constant temperature, somewhat below its expected ignition temperature, and noting if a reaction occurs with extended time of exposure. If no reaction occurs in a reasonable time, the test is repeated with a fresh sample at a little higher temperature. The test is continued until a reaction is obtained in a short period of time such as several minutes. The autoignition temperature test can be used as a rapid means to determine whether the composition will react at elevated storage temperatures. /3/

Flash point. When easily decomposed or volatile organic chemicals are used, it is desirable to determine whether the vapors are readily flammable, and the temperature at which they ignite. The temperature at which ignition takes place can be determined by means of the flash point test. If the vapors are found to be ignitible below elevated temperatures, the ingredient should not be used unless means are provided to prevent escape of the flammable vapors. /7/

Vacuum stability. The vacuum stability test subjects the sample, while under vacuum, to a selected elevated temperature for a predetermined period of time. If an excessive amount of gas is evolved the material is considered unstable. /4/

Flammability. The flammability test determines the likelihood that a pyrotechnic charge will catch fire when exposed to an open flame. In this test the sample is exposed to an oxyhydrogen flame at a specified distance for a fixed period of time. The time to reaction is noted. /3/

(b) Sensitivity to impact. Sensitivity to impact is another important safety parameter to personnel who prepare, handle, and transport pyrotechnic compositions. The test procedure most often used is the placing of a small sample of the material on a hardened steel plate and dropping a known weight from selected heights. Fresh samples are subjected to weight drops of varying heights until no reaction is obtained. This value is taken as a measure of the sensitivity to impact. /4/

(c) Sensitivity to friction. Qualitative tests may be conducted by rubbing a small quantity of the mixture between unglazed porcelain plates or with an unglazed mortar and pestle. Another test is to place a small portion of the sample on a hard surface and strike it a glancing blow with a hammer. /3/ Friction tests are important when determining safety for processing and transporting the mixture.

A more quantitative test employs a pendulum friction device developed by the Bureau of Mines. The apparatus consists of a supported pendulum to the lower end of which is attached a shoe designed for interchangeability of different types of surfaces. The pendulum is adjusted, before testing the sample, to give a specified number of swings across the anvil. The shoe is permitted to fall from a specified height and to sweep back and forth across the sample held in a steel anvil having deep grooves cut into it at right angles to the line of swing. The sample is first subjected to the steel shoe and if a reaction occurs before ten samples have been tested, the test is discontinued and a fibre shoe is substituted for the steel shoe and the testing is continued. /3/

(d) Sensitivity to moisture (hygroscopicity). The hygroscopic nature of the pyrotechnic material or its ability to absorb moisture from the atmosphere must be known if it is to be considered for military application. The rate at which moisture is absorbed and the weight absorbed will depend on such factors as the particle size of the material and its purity, and the ambient relative humidity. An important parameter with respect to the hygroscopic property of a Pyrotechnic ingredient is its critical relative humidity. This is the relative humidity value below which the ingredient will not absorb moisture and above which it will absorb moisture. The absorption of moisture by an ingredient can affect the sensitivity to ignition, propagation and stability of a pyrotechnic composition. /3,6/

(e) Sensitivity to electrostatic discharge. To evaluate the ease with which a pyrotechnic ingredient or mixture is initiated by electrostatic energy, one places a small sample of the material in a depression of a steel block. The apparatus is adjusted to give the desired number of joules and the needle point is positioned to permit the discharge of the spark when the critical distance between the needle and sample is reached. Reactions such as burning and sparks are recorded. /6, 12, 15/

(f) Sensitivity to initiation (ignitibility). Although pyrotechnic compositions may be initiated by such stimuli as heat, impact, friction and electrostatic discharges, sensitivity to initiation is usually considered as the minimum energy required to cause complete propagation of the composition. Heat is the usual source for this energy and may be accompanied with hot gases or hot solid particles.

There is no established method for determining the ignitibility of pyrotechnic compositions. For special applications varying amounts of igniter compositions have been used, as well as miner's cord at varying distances. Compositions have also been subjected to the flash from varying amounts of blackpowder to obtain an indication of the sensitivity to initiation.

(3) Reactions With Other Materials (Compatibility). Compatibility, which is the ability of an ingredient or composition to remain unaffected when in contact with other ingredients or a container, is an important parameter with respect to sensitivity and storage characteristics. Many combinations of ingredients such as potassium chlorate and red phosphorus are very dangerous, and some ingredients will react with the container material. Table 1-1 lists a number of chemical combinations of common materials that are known to be incompatible. It is especially important that all tools and equipment that come in contact with either ingredients or compositions be meticulously clean because unclean tools may affect the performance and stability of a pyrotechnic composition.

(4) Safe Working Limits. During development of a new item, tests should be conducted to determine the consequences of accidental initiation.

TABLE 1-1. HAZARDS OF PYROTECHNIC INGREDIENTS

All items are assumed to be comparatively finely divided, and some of the metals and nonmetals are in the form of dust. Oxidation products that are substantially inert are not included. Degree of hazard may be increased by decreased particle size and increased temperature, and may be affected by presence of moisture or air. Impurities may alter sensitivity to reaction.

FUELS

Inorganic (metals, alloys, and nonmetals): In the finely divided state react vigorously with oxidizing agents. Easily ignited in air by flame or spark. Many are pyrophoric when very finely divided. Contact with water should be avoided.

Fuel	Hazard
Alkali metals:	React violently with water; possible explosion. Oxidize on exposure to air. React violently when heated with CO_2, halogens, and chlorinated hydrocarbons. Keep under kerosene.
Lithium	Reacts explosively with sulfur. Handle under a blanket of argon or helium gas (not nitrogen).
Potassium	Forms explosive mixtures with chlorinated hydrocarbons. Reacts with nitrates, sulfates, hydroxides, chromates, manganates, silicates. Handle under a blanket of nitrogen gas. Destroy if stored for some time while exposed to air. Small amounts can be disposed by reacting in ethanol. Burn large quantities.
Sodium	Reacts explosively with sulfur; when molten reacts violently with sulfur dioxide. Presents same hazards as potassium.
Alkaline earth metals:	React with moisture and oxidize in air, but much more slowly than alkali metals. Storage under kerosene not necessary.
Calcium	Reacts explosively with hexachlorobensene or sulfur. Reacts vigorously without explosion when heated with titanium dioxide or tungsten trioxide. When finely divided will burn in oxygen at 300°C. Reacts violently with halogens above 400°C. Reacts with fluorine at room temperature.
Magnesium	Dust clouds explode when heated or ignited by a spark. Reacts with chlorinated hydrocarbons and halogens. Reacts when heated with alkali oxides, hydroxides, and carbonates.
Aluminum	Reacts with water and may ignite because of liberated hydrogen. Dust may explode in air. Reacts violently when heated with carbon tetrachloride and other chlorinated hydrocarbons and carbon dioxide. Reacts with halogens. May explode when heated with hexachlorobenzene or tellurium.
Boron	Dust may explode spontaneously in air or when ignited by a spark.
Carbon Black, Lampblack	May ignite or explode spontaneously in air or when heated by flame or spark. Reacts spontaneously with sulfur and drying oils.

TABLE 1-1. HAZARDS OF PYROTECHNIC INGREDIENTS (Continued)

Fuel	Hazard
Copper	Reacts with hydrogen peroxides and organic chlorides.
Graphite	Substantially inert. Difficult to ignite. When ignited burns with intense heat.
Magnesium-Aluminum Alloy 50/50 and 65/35	Presents much the same hazard as magnesium and aluminum.
Manganese	May ignite in air. Can be ignited by an electric spark.
Molybdenum	Oxidized by moisture at room temperature. May explode when heated in air.
Nickel	May explode when heated in air.
Phosphorus	Reacts when heated with alcohol to form ethylene and spontaneously flammable phosphine. Burns in air or carbon dioxide when heated. Reacts with sulfur when heated.
White or yellow:	Ignites spontaneously in air. Reacts with organic materials. Store under water and keep below 44°C.
Red:	May ignite spontaneously in air if it contains sufficient yellow phosphorus. Reacts with organic materials. Mixture with chlorates are extremely sensitive.
Silicon	Reacts with steam at red heat. Reacts with the halogens.
Sulfur	May react explosively in air. May ignite spontaneously in the presence of carbon, lampblack, fats, oils and other organic materials. Reacts violently when heated with mercuric oxide. Reacts explosively when ground together with metallic sodium and with the alkali metals and zinc when heated. Reacts violently when heated with potassium oxide. When heated with ammonium nitrate, the mixture ignites.
Titanium	Explodes spontaneously in air; reaction more vigorous if small amount of water is present. Burns when heated in CO_2 or nitrogen. Reacts when heated with carbon tetrachloride. Pyrophoric when very finely divided. Keep wet with at least 25% water of water plus alcohol. Handle only in inert atmosphere of argon or helium.
Tungsten	May explode when heated in air.
Zinc	May explode when heated in air. Reacts violently when heated with strong alkalies. Reacts when heated with CO_2 or CCl_4. Reacts explosively with sulfur.

TABLE 1-1. HAZARDS OF PYROTECHNIC INGREDIENTS (Continued)

Fuel	Hazard
Zirconium	Reacts when heated with water vapor, oxygen, nitrogen, carbon monoxide and dioxide, halogens, sulfur, carbon, silicon, phosphorus, boron, and aluminum. Fires difficult to extinguish. Pyrophoric when very finely divided. Keep wet with at least 25% water. Handle only in an inert atmosphere of argon or helium.
Zirconium - Nickel Alloy 70/30, 30/70	Less reactive than either nickel or zirconium.

Inorganic Compounds: Not usually hazardous by themselves. Vary in ease of decomposition by heat and reactivity with oxidizing agents.

Fuel	Hazard
Antimony Sulphide	Reacts with hot water and steam. Decomposes on heating.
Calcium Phosphide	Reacts with water and spontaneously liberates flammable phosphine. May explode when heated by a flame. Liable to spontaneous combustion.
Calcium Silicide	Reacts with water and liberates flammable silicon hydrides. When heated it decomposes and may burn or explode.
Ferrous Sulfide	Reacts with water.
Zirconium Hydride	Reacts violently on heating with easily reducible oxides. Reacts at red heat with all except the noble gases forming nitride, carbide, oxide, etc. Dry powder can be ignited by a static spark or shock.

Organic Compounds: Combustible; most represent no other particular hazard by themselves. Only a few are used as fuels, although many organic ingredients are used as additives. May react with oxidant present but their reaction as a fuel is secondary.

Fuel	Hazard
Anthracene	Heated vapors may explode when ignited in air. Reacts when heated with oxidizing agents, particularly strongly with CrO_3.
Dextrin	No particular hazard.
Lactose	Reacts vigorously when heated with oxidizing agents, expecially chlorates. Dust can be ignited in air by an electric spark.
Sugar	Reacts when heated with oxidizing agents, particularly chlorates.

OXIDANTS

Inorganic Compounds: Form sensitive mixtures with powdered metals and organic materials. The sensitivity and reactivity are increased as the temperature is raised, and may result in explosion. Avoid exposure to water vapor as many oxidants are hygroscopic. The sensitivity of mixtures containing the following oxidizers decreases in the following order (approx.): chlorates, perchlorates, peroxides and some oxides, nitrates, chromates. These classes and their individual compounds are listed below in alphabetical order.

Chlorates

Barium Chlorate	Reacts when heated with finely divided metals, ammonium salts, sulfur, sulfides, phosphorus, finely divided organic materials, oils, greases, charcoal and solvents.

TABLE 1-1. HAZARDS OF PYROTECHNIC INGREDIENTS (Continued)

Oxidant	Hazard
Potassium Chlorate	Sensitive to shock or heat and when mixed with reducing materials such as sugar, charcoal, shellac, starch, sawdust, oils and grease, lint, vegetable dusts, alcohols and other organic solvents, powdered metals, ammonium compounds, sulfur, sulfides, and phosphorus.
Chromates	
Barium Chromate Lead Chromate	React vigorously when heated with finely divided metals and easily oxidizable materials.
Nitrates	
Ammonium Nitrate	Reacts vigorously when heated with powdered metals, galvanized iron, lead solder, sulfur, sulfides, phosphorus, chlorides, nitrates, chlorates, nitrites, organic nitro compounds, charcoal and oxidizing carbonaceous material. Ignites when heated with sulfur.
Barium Nitrate	Reacts vigorously when heated with reducing materials, particularly phosphorus, sulfur, and sulfides.
Calcium Nitrate	May be exploded by shock, heat, flame or chemical action. Reacts vigorously when heated with boron, phosphorus, sulfur, sulfides, sodium acetate, and flammable organic materials such as oils, tallow, and fibrous materials.
Lithium Nitrate	May explode when heated with reducing agents, phosphorus, sulfur, and sulfides.
Potassium Nitrate	Can be detonated by shock. Reacts vigorously when heated with boron, phosphorus, sulfur, sulfides, sodium acetate, and flammable organic materials such as oils, tallow, and fibrous materials. Handle as an explosive.
Sodium Nitrate	Dangerous fire and explosion hazard when heated alone or with reducing materials.
Strontium Nitrate	Reacts vigorously when heated with phosphorus, sulfur, sulfides, and reducing materials.
Oxides and Peroxides	
Barium Peroxide	May explode when heated with magnesium, aluminum, zinc, phosphorus, sulfur, sulfides, charcoal, and other reducing materials. Reacts with moisture.
Chromic Acid	Reacts vigorously when heated with most metals, acetic acid, acetone, alcohol, glycerine, flammable and reducing materials.
Cuprous Oxide	Explodes when heated with powdered magnesium.
Ferric Oxide	When heated can act as an oxidizer, e.g., thermite; reaction with aluminum.

TABLE 1-1. HAZARDS OF PYROTECHNIC INGREDIENTS (Continued)

Oxidant	Hazard
Ferrosoferric Oxide	When heated can act as an oxidizer.
Lead Oxide	May explode when heated with magnesium.
Lead Peroxide	When heated reacts with reducing materials and may ignite. Mixtures with red phosphorus, sulphur, sulphides, and charcoal are sensitive to impact and friction. May detonate when heated with powdered aluminum, magnesium, or zinc.
Lead Sesquioxide	When heated with magnesium may detonate.
Lead Tetroxide	When heated reacts with reducing materials. May explode when heated with magnesium.
Manganese Dioxide	Reacts when heated with reducing agents. Forms sensitive mixtures with red phosphorus, sulfur, sulfides and hyposulfides.
Molybdenum Trioxide	When heated reacts with sodium, potassium, magnesium, aluminum and silicon and is itself reduced to the metal. When heated with zinc there is only a partial reduction. Reacts with halogens and molten potassium chlorate.
Silicon Dioxide	Reacts when heated with metals. May explode when heated with magnesium.
Strontium Peroxide	May be detonated by heat, shock,or catalysts. Reacts violently when heated with reducing materials, magnesium, aluminum and zinc. Mixtures with red phosphorus, sulfur and sulfides are sensitive to impact, friction and heat. Reacts with water.
Zinc Oxide	Hydrolyzes slowly in water. May explode when heated with powdered magnesium.
Perchlorates	
Ammonium Perchlorate Barium Perchlorate Calcium Perchlorate Lithium Perchlorate Potassium Perchlorate Strontium Perchlorate	Behave very similarly. When heated may ignite and explode. When heated with powdered metals, particularly magnesium and aluminum, sulfur, sulfides, phosphorus, and combustible carbonaceous material, react violently.
Polychlorotrifluoroethylene	Comparatively inert. Under conditions of high shear, where fine particles of fresh metal are exposed, soft metals such as aluminum and magnesium react vigorously.

TABLE 1-1. HAZARDS OF PYROTECHNIC INGREDIENTS (Continued)

ADDITIVES

This includes a variety of materials, most of which are added in comparatively small proportions to compositions for special purposes such as intensifiying color, retarding, binding. The oxidants listed below result from the burning of the compositions. The miscellaneous materials have been grouped below for convenience.

Additive	Hazard
Carbonates and Bicarbonates	
Barium, Calcium, and Magnesium Carbonate; Potassium and Sodium Bicarbonate	React with mineral acids, giving off CO_2. Represent no hazard. Used as coolants or antiacids.
Catalyst (for polymerization)	
Cobalt Naphthenate	Marketed as a 6% solution in mineral spirits. Spirits are volatile and flammable and may explode when heated in air. Explodes on mixing with methyl-ethyl ketone peroxide (see Lupersol DDM under Fuels--Organic).
Color Intensifiers	
Inorganic	
Barium and Strontium Chlorides	Present no particular hazard.
Organic	
Dechlorane	Comparatively inert.
Hexachloro-benzene	Dangerous when heated with alkalies or metals. Explosive chloracetylene is produced.
Hexachloro-ethane	When heated to decomposition produces toxic fumes of chlorides. Relatively inert.
Polytetra-fluoroethylene (Teflon)	When heated reacts with molten alkali metals and fluorene.
Polyvinylchlo-ride	When heated reacts with alkalies.
Dyes	May behave as fuels and react when heated with strong oxidizers.
Explosives	
Black Powder	Detonated by friction, heat, impact, or by electric spark.
Nitrocellulose	When dry extremely sensitive to shock and friction. Easily accumulates static charges. Highly inflammable and explosive. Decomposition on storage is accelerated by acids and alkalies, resulting in possible fire or explosion.
Tetranitro-carbazole.	May explode on heating.
Oxalates	
Barium, Calcium, and Strontium Oxalate	Give off dangerous CO.
Oxides	
These result from the burning of compositions containing the corresponding metal or metal compound.	
Alkali Oxides Potassium and Sodium Oxides	React with water with the evolution of heat, which in the presence of organic material may be sufficient to cause ignition.
Alkaline-earth Oxides, Calcium, Barium, and Magnesium Oxide	

TABLE 1-1. HAZARDS OF PYROTECHNIC INGREDIENTS (Continued)

Additive	Hazard
Aluminum Oxide	Reacts vehemently when heated with calcium carbide.
Chromic Oxide	When heated decomposes suddenly at 330°C.
Potassium Oxide	Reacts violently when heated with sulfur.
Titanium Dioxide	Reacts vigorously when heated with metallic calcium.
Solvents	
Acetone	Vapors form an explosive mixture with air. Reacts vigorously with oxidizing agents, particularly chlorates, peroxides, and chromic acid.
Alcohol	Vapors form an explosive mixture with air. Reacts vigorously with oxidizing agents, particularly chlorates, chromic acid and sodium peroxide. Reacts with phosphorus at 215°C forming ethylene and spontaneously flammable phosphine.
Carbon Tetrachloride	Reacts slowly with water forming hydrochlorine acid. Reacts when heated with alkali and alkaline earth metals, peroxides, and metal powders such as aluminum, iron, and sodium peroxides.
Dibutylphthalate	Flammable. When heated reacts with oxidizing agents.
Kerosene	Vapors may explode when heated in air. Reacts when heated with halogens and oxidizing agents such as CrO_3, Na_2O_2.
Binders	
Asphaltum	Dust cloud may explodein air.
Calcium Resinate	When heated reacts with oxidizing agents.
Calcium Stearate	No particular hazard. Acts as a retardant.
Castor Oil	Reacts when heated with oxidants, particularly chlorates.
Ethycellulose	Reacts on heating with oxidizers. Dust may be ignited by an electric spark.
Gum Arabic	No particular hazard.
Gum Tragacanth	No particular hazard.
Laminac 4116	The original mixture contains such small amounts of unstable peroxides (e.g., methylethyl ketone peroxide, benzoyl peroxide) that the mixture may be considered merely as combustible.
Linseed Oil	Reacts when heated with sulfur or oxidizing agents, particularly chlorates.
Parlon	Will ignite in the flame of a Bunsen burner, but the flame is self extinguishing. Gives off HCl on heating to decomposition.

TABLE 1-1. HAZARDS OF PYROTECHNIC INGREDIENTS (Continued)

Additive	Hazard	Additive	Hazard
Shellac	Dust can be ignited by an electric spark. Reacts when heated with oxidizing agents, particularly chlorates.	Thiokol Liquid Polymer LP-2	The monomer is polymerized by various organic peroxides. Conventional paint driers and PbO_2 are also excellent.
Stearic Acid	No particular hazard.	Zinc Stearate	No particular hazard.

These tests should be conducted on full scale items, when possible, and should test exposure to heat, vibration, jolt, transportation, drop, and so on. The results of these tests can be used to establish safe limits for processing, testing, storage, and disposal.

b. Recognizing and Minimizing Hazardous Situations

Areas in which actual or potential hazards exist should be noted whenever a new item is being developed or an old item is being improved. Every effort should be made to comply with existing regulations on processing, testing, storage, and disposal. As always, good housekeeping should be emphasized and followed.

Safety experts and other experienced personnel should be consulted to help anticipate trouble spots and minimize potential hazards. Supervisory personnel should always be alert to sensitive areas, and must, in turn, teach subordinates to take all essential precautions.

3. PROCESSING PYROTECHNIC MATERIALS

Many possibilities for accidents exist when processing pyrotechnic ingredients and compositions. Potential hazards must be eliminated in each of the following steps that make up the processing procedure.

(1) Transportation

(2) Storage

(3) Grinding

(4) Weighing

(5) Blending

(6) Granulating

(7) Loading

(8) Drying

(9) Assembly

(10) Testing

(11) Disposal

Also, the following basic principles should be applied to each of the above steps.

(a) Adopt a systematic plan for each experiment or operation.

(b) Work with minimum quantities.

(c) Ground all containers and equipment to avoid electrostatic buildup.

(d) Clean thoroughly all containers, tools, and equipment prior to use.

(e) Conduct work in rooms conditioned to 45-55% relative humidity or when ambient humidity is within these limits.

(f) Check all tools for irregularities, and repair or replace as necessary.

(g) Maintain good housekeeping.

(h) Perform as many operations as possible by remote control.

(i) Eliminate unnecessary dusting.

(j) Wear approved safety clothing, and use only approved equipment.

(k) Store completed blends in airtight and moistureproof containers.

(1) Transportation. When moving ingredients and compositions from one location to another, the material should be in airtight, moistureproof, and unbreakable containers. Sensitive compositions should be transported on a cart, not carried.

(2) Storage. Pyrotechnic compositions should be stored in accordance with prescribed regulations. Storage magazines should not be overloaded and ingredients that may react spontaneously if accidently brought in contact with each other should not be stored in the same magazine or chamber. Each magazine should be clearly marked for firefighting purposes.

Containers should have labels, protected by a clear tape, to indicate contents. It is good practice to indicate on the label the type of hazard associated with the materials. Screw cap bottles should not be used for friction sensitive materials.

(3) Grinding. Pyrotechnic materials must often be reduced in particle size to meet granulation requirements. Depending on the type of material, the granulation desired, and the amount to be ground, one may use ball mills, hammer mills, or other types of pulverizers. Before beginning grinding, the machine should be checked for electrical grounding, cleanliness, and working order, and the material should be screened to remove all foreign matter. The material should be ground in small batches, with precautions taken to reduce the dust hazard. All grinding or pulverizing should be performed in remotely controlled rooms that are equipped to eliminate dust. The rooms should be entered only when the operations have been completed, and then a dust respirator should be worn. When grinding heat sensitive materials such as waxes and resins, dry ice or liquid nitrogen can be used to keep the material solid enough to be pulverized. After grinding, one should rescreen materials to remove any foreign materials that may have been introduced during the grinding process.

(4) Weighing. To avoid accidents that may be caused by electrostatic discharges, all weighing must be carefully done on a clean, electrically grounded balance placed on a table whose top is also electrically grounded. The ingredients should be scooped, not poured, from the container and carefully placed in the balance pan. Separate facilities or balances must be used in weighing oxidants and fuels. Explosives should be weighed only behind safety shields. When weighing is completed, the balances should be thoroughly cleaned and all dust traces removed.

(5) Blending. Blending is one of the most hazardous operations, therefore mandatory procedures must be strictly followed, because pyrotechnic compositions vary widely in sensitivity and stability. When preparing an experimental mixture for the first time, one should prepare quantities no larger than 50 grams, then test for sensitivity to impact, friction, heat, and electrostatic discharge. If the composition proves sensitive to one or more of the above characteristics, consideration should be given to selecting another composition or working with the largest quantity consistent with safety and the advice of safety experts. Consideration should also be given to preparing the mixture with a nonflammable volatile liquid, which can later be removed by drying. Wet blending is generally considered safer than dry blending and is used when a mixture is known to be sensitive. When using a liquid for mixing, adequate ventilation must be provided to remove the fumes.

(6) Granulating. After blending, some pyrotechnic compositions are granulated to make them free flowing and easier to handle during pressing. As with other machines, the granulator must be electrically grounded, clean, and in proper working order before the start of operations. If the composition being granulated contains a volatile ingredient there must be adequate ventilation and provisions made to remove it.

(7) Loading. The loading of a pyrotechnic item is most commonly done by consolidating the charge by a press or by vibrating the loose powder into the item. Before beginning any loading operation, the sensitivity characteristics of the composition must be known. Only approved machinery in proper working order should be used. Strict adherence to standard operating procedures and the use of prescribed safety equipment is mandatory. The loading operation should be conducted with barricaded and well-grounded equipment that can be operated remotely.

Except for some loose smoke and flash compositions, pyrotechnic materials are generally pressed into bullets or into cylindrical paper, plastic, or metal cases, in the form of candles. The candles burn progressively from one end to the other -- "cigarette-type" burning.

Because of the pressure used in a pressing operation, friction is the greatest hazard. Every precaution must be taken to avoid friction between moving parts of the press and loading tools. Constant inspection is required to keep the press and tools deburred, aligned, and meticulously clean.

Operating procedures should not only describe the method of operating the press and general safety precautions, but also prescribe what to do in case of any irregularity in the functioning of the machine. For example, if an excessive temperature rise is noted in any part of the press, the press should be shut down immediately; if a shaft or any part should freeze on a bearing surface, no attempt should be made to loosen the part by force until all ignitible material is removed from the area; if any oil leak develops the press should be repaired before continuing; if the mixture is contaminated or suspected of being contaminated it should be disposed of.

Keeping the press meticulously clean cannot be overemphasized. Should any of the composition get between the ram and the side of the mold, binding may occur, a hazardous condition. Should binding occur no attempt should be made to remove the ram manually. This operation should be done remotely behind barricades by means of a press. The ram should be extracted slowly to avoid heating the composition. Precautions should be taken to prevent injury to personnel and damage to property in the event of an accidental initiation. Thus, it is extremely important that all parts in contact with the mixture be cleaned before each pressing.

If the composition is considered unsafe to load by pressing, or if extreme consolidation pressures are not required, the composition may be compacted by vibration. This procedure should be carried out by remote control with all precautions taken to reduce the amount of dusting. The optimum vibration frequency and amplitude depend on the size, weight, and shape of the container, and the flow properties of the powder. All equipment and the operating area should be carefully cleaned after completion of the loading operation.

(8) Drying. When a composition has been prepared with the use of a carrier liquid, it should be thoroughly dried before loading. The major part of the liquid should be removed by air drying in a ventilated room, with the remaining liquid removed by drying in an explosion-proof, temperature-controlled oven. Provisions must be made to remove the vapor as released. The safe drying temperature of the composition must be known before placing it in the heated oven.

(9) Assembly. When pyrotechnic devices are assembled, controlled operations are desirable. The temperature and humidity should be carefully controlled and dusting of the composition should be kept at a minimum. The least practical number of completely assembled items should be kept in a work area.

(10) Testing. The completed item must be tested in accordance with local or standard regulations. Equipment should be checked for working order and electrical grounding. Barricades should be used if a detonation may occur. If an item fails to function, no attempt should be made to determine the nature of the malfunction until sufficient time has elapsed to assure that the item is not reacting. The "dud" should be handled cautiously, preferably by remote control, and disposed of as soon as possible. Care should be taken to avoid inhaling the reaction products of burning compositions because many of these are toxic.

(11) Disposal. Safe disposal of pyrotechnic ingredients and materials is a problem because of the flammable, explosive, or toxic nature of many of these. Occasionally, small quantities of acids, alkalies, and acetones can be simply disposed of down the drain, provided abundant cold water is used. But even completely water-soluble solvents such as acetone and ethanol must be diluted with large volumes of water to avoid flammable vapors that may become a fire hazard in the drain. Also, there is always the possibility of chemical action between different materials occurring in the drain. Another drawback to this disposal practice is the damage that corrosive chemicals such as acids may have on the drain pipes, and the hazard to personnel who service or otherwise maintain the drainage system.

To minimize the above problems, it is necessary to segregate wastes, with the ultimate disposal carried out in strict accordance with the local operating procedures for each laboratory or plant. Particular care must be exercised to prevent placing materials that might react with each other in the same container. Special waste containers should be used to segregate the waste materials, and the containers must be clearly labeled as to their contents.

Most laboratories and plants specify the maximum amount of waste that may be safely stored. This limit must never be exceeded. Keeping below this limit requires regular, planned trips to the waste disposal area.

The waste disposal area should be located far enough from the laboratory or plant so that any fire, smoke, or fumes produced will not be objectionable or hazardous to personnel. The area should be fenced and posted so that it is clearly recognizable as an area specifically and exclusively reserved for disposing of chemicals.

When disposal of extremely hazardous compositions is being conducted, the handling should be followed step-by-step from the time they are placed in disposal containers until their ultimate disposal. Only then can supervisory or safety personnel be assured that all workers are adequately protected from hazard.

4. ELECTRICAL HAZARDS

The increasing use of electrical equipment and flammable materials in the laboratory and plant adds to the possibility of accidents. The electrical installation must preclude accidental ignition of flammable liquids, vapors, and dust released to the atmosphere. This necessitates the use of explosion-proof lighting fixtures, nonarcing and nonsparking switches, circuit breakers, motor starters, receptacles, and so on. All electrical machinery must be equipped with explosion-proof motors, and must be firmly connected to an approved electrical ground. Portable lamps and flashlights must be of the approved type because fatal explosions have been caused in dust-filled rooms by the arc from the switch of an ordinary flashlight.

Besides the hazards presented by electrical equipment, the hazards associated with static electricity are always present. Proper safety precautions such as wearing conductive shoes, the minimum use of outer woolen and silk clothing, and the electrical. grounding of laboratory tools and utensils, and conductive floors and working surfaces both properly grounded must be observed faithfully. In many cases personnel performing the operation must also be electrically grounded to insure safety.

5. FAILURE OF SERVICES

An electrical power failure, loss of cooling water, or loss of almost any other service such as telephone presents a potentially hazardous situation. This is particularly true when working with reactive chemicals. In anticipation of the loss of services, procedures should be developed to reduce the hazardous situation in as short a time as possible.

6. SAFETY EQUIPMENT

So far, this chapter has discussed safety mainly with respect to ingredients, compositions, and processing. Another point of utmost importance is personal safety equipment. The following items are typical of such equipment:

(1) Flameproof coveralls, gloves, coats, blankets

(2) Protective eye devices

(3) Face shields

(4) Sweat bands

(5) Foot guards

(6) Safety conducting shoes

(7) Industrial gas masks

(8) Chemical cartridge respirators

(9) Dust respirators

(10) Pyrotechnic cream

(11) Soap

(12) Towels

(13) Nonsparking tools

(14) Safety showers

Ordnance Safety Manual, AMCP 706-224 specifies that these devices must be used wherever necessary. The Standard Operating Procedures at each laboratory or plant specify when and how the safety equipment should be used. All laboratory personnel should be thoroughly trained in the use of protective equipment. The correct safety equipment for a particular operation should be selected by the supervisor in charge of the operation before any work is begun.

Soap is an important safety device that is frequently overlooked. The importance of personal cleanliness must be stressed. Frequently washing the hands and face greatly reduces the dangers of inflammation or poisoning when working with toxic materials. The importance of thoroughly washing the hands before eating is obvious.

7. FIREFIGHTING

Proper protection against fires in the laboratory or plant stems mainly from good housekeeping, and observing proper precautions in carrying out work. Personnel should be instructed in the special hazards of materials being handled. The Ordnance Safety Manual and local regulations give procedures that must be followed in the event of fire. Personnel should not approach or attempt to fight a fire while wearing clothing contaminated with pyrotechnic materials or explosives. In the event of a fire, all operations in the building stop immediately and all personnel prepare to assist the fire department. Laboratory and plant personnel must know the location of the nearest fire alarm and firefighting equipment, and must be thoroughly familiar with the use of the equipment. Improper firefighting techniques, such as the use of water on burning compositions, can increase the hazard of a laboratory or plant fire. It must be remembered, however, that the best firefighting equipment available cannot prevent fires; that is the job of laboratory and plant personnel.

8. CLASSIFICATION OF PYROTECHNICS

The only general classification of pyrotechnic ingredients and compositions is found in Army Ordnance Safety Manual AMCP 706-224, where materials are categorized for quantity storage safety distances but not for laboratory and plant use. Individual facilities may establish safety categories but there exists no general systematic scheme for laboratory or plant. Table 1-2 gives the safety classification that appears in the Ordnance Safety Manual. /2/

9. CONCLUSION

Safety is the responsibility of all laboratory and plant personnel. Each supervisor must be responsible for the education of personnel under him and must promote safety by example. The supervisor must assure himself that everything is being done to avoid injury to personnel and damage to property. The introduction of new ingredients requires constant evaluation of safety practices to avoid potential hazards to personnel. New requirements and work on new items call for a program of education to supply new safety information and to develop new skills. S'.eets should be prepared for each composition giving detailed information on the sensitivity and toxicity, and special instructions concerning the preparation of the composition. Any accidents should be thoroughly investigated for causes, and then steps taken to remove these causes to avoid similar future accidents.

10. REFERENCES

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TABLE 1-2. SAFETY CLASSIFICATION OF PYROTECHNIC INGREDIENTS, FORMULATIONS, AND END ITEMS

CLASS 1

Aluminum powder (packed and stored in original shipping containers or equivalent)
Charge, spotting, AP, practice M8
Chlorates (packed and stored in original shipping containers or equivalent)
Firing devices
Fuse lighters
Fuse, safety
Magnesium powder (packed and stored in original shipping containers or equivalent)
Mines, AP, practice, T34
Nitrates, inorganic (packed and stored in original shipping containers or equivalent)
Perchlorates (packed and stored in original shipping containers or equivalent)
Peroxides (except high strength hydrogen peroxide, packed and stored in original shipping containers or equivalent)
Squibs, commercial
Thermite
Zirconium (types I and II, spec FED-1655, packed and stored in original shipping containers or equivalent)

CLASS 2

Bomb, photoflash, M122, w/o burster
Chemical ammunition, groups C and D when not assembled with explosive components
Grenades, illuminating
Military pyrotechnics (exclusive of class 4 and 9 items)
- Flares
- Illuminants
- Incendiary ammunition including projectiles, bombs, and grenades exclusive of HE-I rounds
- Igniters and tracer units (for ammunition)
- Signals, including signal lights, smoke signals, and obscuring smoke

Projectiles, illuminating, when not assembled with explosive components
Pyrotechnic materials (exclusive of class 9 and 10 items) when not packed or stored in original shipping containers or equivalent, such as:
- Chlorates
- Illuminating, flare, or signal compositions which have been consolidated in the final press operations
- Perchlorates
- Peroxides
- Powdered metals (including zirconium, types I and II spec FED-1655)
- Thermite and other similar incendiary compositions

Spotting charges (cartridges for miniature practice bombs)

CLASS 3

Grenades, practice, with spotting charge
Mines, practice, with spotting charge or fuze (except Mine, AP, practice, T34)
Simulator, M116

CLASS 4

Bombs, chemical loaded, with explosive burster
Cartridge, HE, colored marker
Cartridges, illuminating
Mines, antipersonnel (bounding type)

CLASS 8

Blasting caps
Detonators (except concussion type, M1)
Percussion elements
Primers, electric (for small arms and 20-mm ammunition)
Primers, percussion (small arms ammunition)

CLASS 9

EC blank powder
Tetrazine, TNR, lead styphnate, and lead azide primer compositions
Black powder
Double base propellant with web thickness less than 0.0075 in., regardless of NG content
Double base propellant containing more than 20% NG
Tracer, igniter, incendiary illuminating, flare, and first fire compositions up to and including final consolidation
PETN, TNT, and small-arms primers not packed in accordance with approved Ordnance Corps drawings or specifications, and not packed for commercial transportation
Tetryl, RDX
MOX-2B
Quickmatch

CLASS 10

Class 4 items, when not packed and stored in accordance with Ordnance drawings
Bomb, photoflash
Cartridge, photoflash
Simulator, M115
Mines, antipersonnel

CHAPTER 2 PROCESSING PROCEDURES AND EQUIPMENT

1. PROCESSING

This chapter presents the basic principles involved in processing pyrotechnic compositions. Because of the wide variety of ingredients and compositions handled by research and development and operating personnel, general procedures, rather than specific directives, are given. A composition is processed only after its safe working limits are determined. To assure the optimum performance, every phase of processing should be carefully controlled. Supervisors should prepare Standard Operating Procedures (SOP's) for each composition, point out any unusual hazards, and indicate necessary precautions. All personnel should be thoroughly familiar with the safety measures discussed in Chapter 1, Safety in the Pyrotechnics Laboratory and Plant.

a. Transportation

Pyrotechnic ingredients and compositions should be transported in their original containers whenever possible. Materials from which samples are to be removed should be preblended for uniformity, then placed in clean, dry containers that will not contaminate the contents. Containers should be hermetically sealed and labeled to conform to local regulations for internal transportation and ICC regulations for off-facility shipment.

b. Storage

(1) Facilities. Storage facilities will differ depending on type, quantity, and size of material under development or manufacture, but they should always be consistent with best safety practice. They should be conveniently located, adequate in size, well lighted, and fireproof. Type and quantity of stored material should be clearly marked on all containers. Fuels and oxidizers should be stored separately. Also, explosives, fuzes, primacord, pyrowire, and associated items should be separated. The smallest quantity of ingredients or compositions, and the smallest number of loaded components necessary to operations should be on hand. Each item should be stored in the recommended type of container under the recommended conditions.

(2) Safety Regulations. Ordnance Safety Manual AMCP 706-224 covers class of fire and explosive hazard, quantity and distance tables, acceptable construction, and barriers for large scale plant operations for the following storage conditions:

1. General storage of bulk chemicals
2. Limited bulk storage of chemicals adjacent to or near composition mixing and blending operations
3. Bulk storage of processed compositions
4. Limited bulk storage of processed compositions adjacent to or near filling and loading operations
5. Bulk storage of loaded components of end items
6. Bulk storage of end items
7. Storage of selected samples prior to evaluation testing
8. Storage under accelerated or long term environmental test conditions
9. Storage of scrap prior to disposal
10. Storage of materials under liquid

AMCP 706-224 should be consulted as a first step toward making a decision about storage of an unfamiliar ingredient or composition. If safety manuals and local regulations do not give explicit storage instructions for a new item, the supervisor, local safety representatives, or other experts should be consulted. Also, every laboratory and plant should have a continuing safety program that includes periodic inventory of samples, ingredients, and compositions to keep the overall quantity of materials to the minimum required to operate efficiently.

(3) Storage Under Liquid. Ingredients such as white phosphorus are commonly stored under water or a water-alcohol mixture to prevent combustion. The water-alcohol mixture prevents freezing under uncontrolled temperature storage conditions. Removing frozen materials from containers is especially hazardous because of possible friction and impact. Finely divided metals such as zirconium and certain explosives are also stored under water to avoid ignition by friction or static spark discharge from containers.

Special care should be taken when handling finely divided metals that have been stored under liquid. If they are ignited while damp, an oxidation-reduction reaction occurs that can produce a hydrogen explosion. Also, after long standing under water they may settle to the bottom of the container in a tight compact mass. Spatulas or tools should not be used to break up this mass; instead, a stream of water should be directed against it or, if sufficient water covers the mass, the container cover or lid may be replaced tightly and the whole container shaken by remote control or placed on a ball mill until the contents are converted to a slurry. Containers should be inspected periodically for leaks or corrosion.

c. Grinding.

Size reduction techniques for pyrotechnic ingredients are similar to those used in propellant and explosive operations. The same safety precautions apply because many oxidants undergo explosive decomposition, and fuels form explosive mixtures with air. It is preferable to procure ingredients in the particle size required, but if this is not possible, facilities for size reduction should be established.

Grinding equipment for pyrotechnic items must be properly designed, maintained, and periodically inspected for electrical grounding, clearance of moving parts, lubrication, and seals. Seals, especially, may require frequent opening, cleaning, and repacking because of accumulation of ground material. Corrosion-resistant construction should be considered when grinding oxidants inasmuch as water is used to remove the oxidants. Remote control should be designed into all grinding equipment and, if possible, grinders should be charged and material removed without the operator present in the same room.

Friability, hardness, hygroscopicity, and moisture of the material, as well as the size required, will all affect grinding operations. Types of size reduction equipment commonly used in pyrotechnics are described below.

(1) Ball Mills. Ball mills, which are used for wet grinding and fine particle size reduction, vary depending on the size and design of the mill and balls, type of ball material and wear, properties of material being ground, and the weight of the wet or dry charge. One type of ball mill has a 4.5 in. inside diameter and a hemispherical end, against which a stainless steel or aluminum ball rests. The ball, from 2 to 4 in. in diameter, is selected so that the unit force at point of tangency is not excessive for the sample of material. The ball rolls over the particle, without exceeding a maximum force, until it is crushed. The mill is emptied remotely by tipping below the horizontal, the ball is caught on a screen, and the milled product is washed through the screen.

Pebble mills with nonmetallic liners, or ceramic or granite jars are used where metallic contamination must be avoided. Grinding of heat. sensitive ingredients is often done with liquid nitrogen as the wetting agent and coolant. The mortar and pestle may be used for size reduction but extreme caution should be exercised when grinding energetic materials.

(2) Pulverizers. Although pulverizers may vary in screen size, mill size and diameter, and rate of feed, the following genera€ considerations usually apply.

Prior to grinding, the material should be screened for lumps and foreign material and, if moist, oven dried. Receiving containers and the chute bag should also be dried. The pulverizer should be checked for proper operation, and electrical equipment and containers should be inspected. The grinding operation should be monitored remotely; checking speed of feed, screen rate, current load on mill, feed motors, and temperature of mill. The mill should be up to speed before starting the feed and should be stopped only after the feed has been stopped and the mill emptied. The receivers should be removed only when the mill has stopped. For greater control of particle size fractions, cyclonic separation may be used for particle size classification (see below).

d. Classification

Classification is the process of obtaining specific size fractions of finely divided powders by means of sieves or screens, elutriation by air or liquid, sedimentation, centrifuging, or by cyclone classifiers. Sieving is used for particles coarser than 44 microns, and may be done wet or dry. The other methods are for particles in the subsieve range using dry powder. Chapter 3, Particle Size Procedures, covers in detail the classification of pyrotechnic ingredients.

e. Weighing

The performance of a composition depends primarily on the accuracy with which the ingredients have been weighed. Although other unit operations affect the performance of a formulation, they cannot overcome a weighing error.

The size and type of balance used depends on the quantity and volume of material, and the accuracy desired. Laboratory trip balances are used for small quantities; and platform scales, for larger amounts. Balances and scales should be cleaned and checked before each use and readjusted if necessary.

Prior to weighing, ingredients should be dried and screened to remove extraneous materials and lumps. Oxidants and metals should be weighed separately on electrically grounded balances. To insure safety, dusting and spillage must be avoided. Any material unavoidably spilled should be immediately disposed of. After weighing, the material should be transferred immediately to the blender, or placed in clean, hermetically sealed containers until used.

f. Blending

Blending has a marked effect on the ultimate performance of a composition because in this procedure the ingredients are brought into intimate contact with one another to form a homogenous mixture. Whether blending is wet or dry, it should be checked and controlled by analytical procedures to assure homogeneity. For example, insufficient blending time will result in a nonhomogenous mixture, whereas excessive blending time may also result in nonhomogeneity because of unblending.

Besides blending time, factors such as density, volume, particle size, or specific surface of the ingredients affect the final homogeneity. If density and particle size differ markedly for each ingredient, a volatile solvent or binder may be added during blending to minimize segregation. Suitability of the blender is also important as some blenders are suited for either dry or wet blends, whereas others can be used for both. The final volume of the mixture should be optimum for the capacity of the blender. This amount is best determined by using test batches, and checking the homogeneity of the batches at various blending time intervals.

The blender should be placed in a separate airconditioned room or bay provided with adequate illumination and a fume removal system. An electrical interlock system should be used so that the blender will not operate while the doors are open, or while the operator is in the room. Remote controls should be used for all blending operations, with the operator behind a reinforced wall provided with a shatterproof porthole. A mirror in the room is sometimes needed to permit the operator to watch the blending. The room should have a weak wall and an explosion-proof roof. All electrical components, fixtures, and equipment must be explosion proof and electrically grounded. All these items should be periodically inspected. Prior to each blend, the equipment should be inspected for defects, and the blades and scrapers carefully adjusted for clearances. Regulations regarding explosive and personnel limits and safety accessories must be strictly adhered to.

The most commonly used procedures and equipment for blending, which is usually a batch process, are described below.

(1) Dry Mixes. The blending of powders without a solvent or binder may be performed in a conical blender, twin shell blender, or a ball mill. The conical blender is a large steel globe fitted longitudinally with steel baffles. All the ingredients are added to the tumbler at one time. The mixing action is obtained by the revolution of the blender. As the ingredients are carried around by the baffles they are dropped toward the bottom and intermixed.

The twin shell blender (V-blender) is formed from two cylinders cut at an angle and joined together in a "V." Rotation of the blender provides an intermeshing action of the powdered ingredients when the two cylinders combine their flow. Other devices may be incorporated into the twin shell blender to assure rapid mixing.

A ball mill (see under Grinding) can also be used for dry blending by replacing the metal or ceramic balls, for safety reasons, with rubber stoppers. The optimum weight of charge, stoppers, and blending time for each new composition should be determined by preblending.

(2) Wet Mixes. Compositions that are considered insensitive to impact and friction may be prepared by forcing the mixture of ingredients through a coarse screen by means of a rubber stopper. The process is repeated until visual observation indicates uniformity has been obtained. The blending operation should be done behind a barricade, and the hands and face protected by asbestos gloves and a face shield. Although there are many types of blenders available for use with a solvent or binder, the muller type is most commonly used for pyrotechnic compositions. In this type of mixer, the ingredients are combined by an intensive action simulating the mortar and pestle. Within a circular blending pan is a wide heavy muller wheel(s) which is mounted to be vertically adjustable. Plows or scrapers clean the sides and bottom of the pan and force the composition into the path of the mullers during rotation of the pan or mullers. The mix must not be too fluid or there will not be enough friction to rotate the muller(s), and it must not be too tacky or it will build up in front of the plows. Optimum operating conditions should be determined by pretesting.

The usual blending procedure is to first spread a thin layer of the fuel(s) in the pan. The solvent or binder is added and the blender is operated for about five minutes. The remaining ingredients are then added and operation continued until blending is complete. It may be necessary to stop blending periodically to scrape down the sides and bottom of the pan with sparkproof tools to assure homogeneity. Dry areas should be moistened with solvent before scraping.

When a blend is completed it should be removed by remote control and used immediately to avoid segregation, or placed in a hermetically sealed container and preblended prior to use. If the blend has been made with a volatile solvent it should be dried before use (see below).

g. Granulating

Pyrotechnic compositions prepared without a binder may be difficult to pellet because they lack freeflowing properties. To improve the flow characteristics, and also to reduce the tendency to dusting and segregation, and to control burning rate, a nongranular powder is converted to a granular material of a selected size. A dry powder can be granulated by first adding a binder or solvent for the desired consistency, and then forcing the material through a suitable screen. If a large quantity of material is to be used, the material is then dried, and if necessary, rescreened prior to use. The granulating operation should be conducted remotely, if possible, and when solvents are used provision should be made to remove them rapidly.

h. Loading

After blending, the composition is loaded into a test vehicle or end item. All loading operations should be performed by remote control, with operating personnel behind reinforced protective barricades. For purposes of loading, compositions may be classified as follows:

(1) Illuminants and Smokes. These compositions usually contain a binder, and are loaded by consolidating into a case by a hydraulic press. The case, which will later be placed into an end item, may be paper, plastic, or metal tubing.

With small arms and tracers the composition may be loaded directly into an end item. Consilidation is done by placing the case in a split mold to prevent rupture during the pressing operation. Weighed increments are placed in the case and then consolidated at the pressure and for the time previously determined. The loaded container is removed by opening the split mold. The igniter is often pressed with either the first or last increment, and an inert charge may be used to seal the nonigniting end of the item.

(2) Delay Compositions. These are usually handled in the same manner as illuminants and smokes, except that higher pressures are used except when binders are present. Dies are used to support the delay body.

Factors such as the size of the increment, number of increments, consolidation pressure, rate of application,and dwell time all influence the burning characteristics of the consdidated composition. Other factors are the case material and the use of a coating on the interior of the case to make the composition adhere. Voids between the case and the composition may result in a detonation during burning, and scattering of the composition.

(3) Flash and Spotting Compositions. Flash and spotting compositions, because they usually do not contain a binder, are likely to be more sensitive than compositions containing a binder. To minimize loading hazards the composition is loaded by vibration rather than consolidation. This is accomplished by placing the item to be loaded on a vibrating table and charging the case with the composition through a funnel. Vibration of the funnel may be necessary to make the composition flow. The maximum loaded weight of the composition depends on the geometry of the container, the frequency and amplitude of vibration, and the total time of vibration. The composition must be dry because traces of adsorbed moisture will keep it from flowing freely and will result in a lower weight.

i. Drying

Drying may be considered as the removal of a liquid from a gas, liquid, or solid by natural or forced convection. Usually, drying is accomplished by heating the composition at a temperature slightly lower than the boiling point of the liquid present. The temperature may be raised at the end of the drying period to assure removal of final traces of the liquid. Amount of liquid present, vapor pressure of liquid, particle size of solids, porosity of solid, thickness of layer, temperature of oven, and rate of air flow all affect drying rate.

Chemicals as received at the laboratory or plant often contain moisture that must be removed prior to use in pyrotechnic mixtures. The materials are first screened through a coarse screen to break up lumps and remove any foreign material.

Drying is conducted on individual ingredents as well as compositions prepared with volatile solvents, and often on compositions that have been stored. Equipment used varies but usually consists of steam controlled drying room, steam ovens, forced draft and vacuum ovens, and explosion-proof electric ovens. Materials to be dried are placed in trays with a minimum layer thickness. The moisture content should be checked to control drying time.

Although drying procedures may vary to meet local regulations, or because of the nature of a material, the following precautions usually apply.

1. Install equipment in strict compliance with all electrical codes.

2. Equip ovens with covered heating coils and explosion-proof latches. Use double thermostat controls to prevent overheating due to faulty control.

3. Determine whether remote control operation is necessary.

4. Be sure that drying will not increase sensitivity.

5. Be sure that drying will not create a reactive material with possible decomposition.

6. Take steps to eliminate solvent vapors from area.

7. Never charge ovens with incompatible materials.

a. Avoid leaving sensitive materials in ovens over night.

9. Dry extremely sensitive material in high vacuum ovens at maximum temperature of 60°C.

10. Remove solvents in a steam heated, forced draft oven at 60°C.

j. Assembly

This is the final step in readying a composition for performance evaluation and use. Prior to assembly the item should be checked for weight and dimensional requirements, and composition. The assembly room should be air conditioned to avoid moisture pickup by hygroscopic materials, well lighted and safety approved. Only the minimum amount of assembled and unassembled items should be kept on hand.

After the composition is placed into its container, an ignition device such as primer cord, primer, detonator, or squib is added. It is secured with a moisture-proof seal, and the item is marked for identification. The final step may consist of placing the assembled item into a hermetically sealed can.

2. HANDLING AND STORAGE OF PYROTECHNIC DEVICES

Because completely assembled items are often not tested immediately after assembly but stored for future use, there are several precautions that must be observed. The items should be hermetically sealed or jungle wrapped to avoid moisture pickup. If the items are to be transported, they should be firmly packed in a sturdy box so that they will not be affected by vibration. The storage containers should be clearly marked as to contents, and dated. If it is necessary to withdraw a sample from the box, spacers should be inserted to protect the remaining items.

3. DISPOSAL OF WASTE COMPOSITIONS

The reactive and hazardous nature of pyrotechnic compositions makes their disposal a major problem (see Chapter 1, Safety in the Pyrotechnics Laboratory and Plant). The disposal of unique compositions should be undertaken only after consultation with safety experts. The approved method most commonly used is the saturation of waste compositions with motor or lubricating oil. The oil saturated waste is then burned in an approved location. If an ingredient is present that may react with the oil, some other approved flammable liquid should be used.

CHAPTER 3 PARTICLE SIZE PROCEDURES

1, PARTICLE SIZE

This chapter describes methods and techniques of measuring particle size. Sampling techniques, and the treatment of collected data to make analytical results useful to military pyrotechnics, are also discussed. The references at the end of this chapter provide detailed information on fine particle technology.

a. Importance in Pvrotechnics

The output of a pyrotechnic composition depends on its rate of reaction. The rate, in turn, is related to the specific surface and the quantities of the ingredientsin the composition. Because factors such as size, shape, distribution, and surfaceof the particles affect the properties of the particulate material, they must be accurately determined and controlled. These same factors affect the packing properties of the ingredients with the coarser particles packing less densely than the fine particles. This packing, in turn, affects the weight-volume relationship of the particles.

b. Measurement

There is no one accepted method for precisely defining a particle. It is common practice to describe a particle as having a "diameter". With the exception of truly spherical particles, the term diameter is understood to be statistical. Various methods of measuring particle diameter may yield different values.

The methods used in fine particle technology may be classified into two general groups: direct sizing and counting; and indirect sizing.

Table 3-1 lists the most common methods and techniques and gives their approximate ranges. The accuracy and precision of any analytical procedure depends on working with a representative and adequate sample, in which the particles are completely deagglomerated.

2. DIRECT METHODS

a. Microscopv

The microscopic method is used to measure the spatial extensions of single particles and aggregates. This method is useful as the most direct way of determining the shape, size, count, and extent of aggregates. It is indispensable for preliminary examination of powders and is used as the reference for checking other methods.

Both the optical and the electron microscope are used for making particle size determinations; the optical for particles of 0.2 to 100 microns in diameter, and the electron for particles of 0.001 to 5 microns. The optical microscope can be used for particles as small as 0.1 micron if ultraviolet illumination and focusing mirrors are used. With the ultramicroscope, this limit can be extended to 0.01 micron.

(1) Technical Considerations. The most important technical considerations are (1) obtaining a representative and uniform sample from the original material, and (2) dispersing it uniformly on a slide without the formation of agglomerates. Often, dispersing or deagglomerating agents are used when a wet preparation is made. The preparation of a sample for examination depends on the size of the material, and its optical properties. Particle counting, with optical microscopes, can be done by special graticles (ocular micrometers), by making photomicrographs of the fields to be counted, or by using microprojection equipment and counting from an image on the screen. The references at the end of this chapter give details for slide preparation, sizing, and counting.

(2) New Adaptations. Among promising newer adaptions of the microscope is electronic scanning, in which a narrow-beam device scans a microscope-magnified image of the sample field and electronically counts and classifies the particles.

TABLE 3-1. PARTICLE SIZING TECHNIQUES AND RANGES

DIRECT	RANGE (microns)
1. Microscopy	
a. Visible light	0.2-100
b. Electron beam	0.001-5
2. Coulter Counter	10-1000
INDIRECT	
1. Sieving	44 and up
2. Sedimentation	
a. Liquid	
(1) Pipette	2-50
(2) Hygrometer	2-50
(3) Manometer	2-50
(4) Balance	2-50
(5) Turbidimeter	2-50
(6) Centrifuge	0.05-50
b. Gas or Air	2-150
3. Elutriation	
a. Air	5-50
b. Air and centrifuge	2-50
4. Permeability	1-1000
5. Adsorption	
a. Liquid phase	0.01-5
b. Gas phase	0.01-5
6. Light scattering	0.05-1

Other techniques to improve the accuracy of particle counting use polarized light, phase contrast, and dark field illumination. These techniques require considerable experience, but are useful in the hands of a skilled technician.

Particles that are too small to be measured by the optical microscope can often be measured by the electron microscope. Because all matter is extremely opaque to electrons, the sample for an electron microscope must be mounted on a thin film or membrane. This membrane must be thin enough to be transparent to the electron beam yet tough enough to withstand the beam and support the particles. Various methods has been devised for making such membranes and mounting them for viewing.

(3) Disadvantages. The microscopic method has certain disadvantages. Particle size data obtained often bear little relationship to the physical or chemical behavior of fine particles. Statistical description of the size of a finely divided material becomes increasingly complex as the uniformity of size and shape decreases. Because it is difficult to measure extremely fine particles, the results are biased to a larger average value. Moreover, because the particles are seen predominantly in one dimension, size is determined by assuming a spherical shape. Size determinations are therefore inaccurate for markedly nonspherical shapes such as plates and needles.

When making counts on a sample with a wide distribution, it is often necessary to change the magnification to cover the distribution. This can lead to a recount of previously tallied particles. When working with high power objectives, constant focusing is required to determine edge to edge dimensions.

The following three practical drawbacks should also be noted it requires more skill than many of the other methods; a relatively long time is needed to prepare samples and make counts; and the equipment is sometimes expensive.

b. Coulter Counter

The Coulter Counter analyzes particle size distributions by particle volume measurement. This instrument determines the number and sizes of particles suspended in an electrically conductive liquid. Its principal advantage over other particle size distribution methods lies in the large number of individual particles that can be scaled and counted during an analysis, Selection of a soluble and conductive electrolyte, however, may pose a problem.

The instrument works in the following manner. A small opening, through which the suspension flows, has an immersed platinum electrode on either side. With concentration adjusted so that the particles pass through this opening substantially one at a time, each particle displaces the electrolyte within the opening for a moment and thereby changes the resistance between the electrodes. This change produces a voltage pulse proportional in magnitude to the volume of the particle and the resultant pulses are displayed on an oscilloscope screen as a series of vertical spikes. These spikes serve as a guide for measurement and also as a monitor of instrument performance. The pulses are also fed to a threshold circuit constructed in such a way that only pulses that reach or exceed an adjustable screen-out voltage level are counted. The electrolyte in the aperture forms the principal resistance between the electrodes.

Deviations from a linear volumetric response become appreciable for nearly spherical particles when particle diameter is more than 30% of aperture diameter. This effect is markedly reduced for elongated particles such as fibers, rods, and platelets, as the prevailing streamline flow causes such particles to be aligned chiefly with the aperture axis.

3. "DIRECT METHODS

a. Sieving

When carried out under standardized conditions, sieving is a rapid, accurate, and reproducible method of evaluating the mass distribution of particulate materials. The results obtained depend on the size and shape of a particle and the shape of the sieve opening. Density, porosity, and surface characteristics are relatively unimportant.

(1) Sieve Sizes. The lower limit of classification by sieves or screens is fixed by the finest mesh sieve commercially available, 44 microns. Sieves produced by an electroforming process can be supplied in mesh sizes of 10-40 microns. But the extremely fine size of the mesh openings increases the tendency of the material to plug the openings, thus resulting in either non-passage of material or inaccurate results. Also, these very fine sieves must be carefully cleaned.

Standard sieves are pan shaped, with a wire mesh bottom of definite and uniform openings. Usually, these openings are square, although round, slit, and other shaped openings are available. Stainless steel is the preferred metal because it is chemically inert and easy to clean. Table 3-2 gives the range of sieves and their characteristics.

(2) Procedure. By using a series of stacked sleeves, with the coarsest screen on top and the finest on the bottom, the powdered sample can be classified into a number of fractions. The sample, usually less than 100 grams, is placed on the upper screen and the stack is given an oscillatory and tapping motion by hand or by machine. The sample will distribute itself on the sieves, depending on the size and shape of the particles and the size of the openings in the sieve. A bottom pan collects the material passing through the finest sieve.

The number of sieves used in a determination depends on the information desired. If the amount of material retained and passing through a sieve of a specific size is required, then only one sieve is needed. If a particle size distribution is wanted, however, as many as five sieves may be used. Sieving time is considered sufficient when the amount of material passing through a screen is negligible. The material remaining on the sieves or pan is removed and weighed. The data are usually reported as percentage passing through or retained on a sieve, or as percentage finer than a certain micron size. These data can be plotted on log probability paper to yield the average particle size and distribution.

(3) Sources of Error. One source of error in sieving may be from the fracture of particles, which will bias the distribution toward the finer size. To make sure there is no change in mesh size of sieves in use for a long time, they should be calibrated periodically with materials of known distribution or measured microscopically.

Interparticle forces, electrostatic charges, and relative humidity may affect the separation of particles. If agglomeration becomes a problem, separation may be made by using a relatively volatile liquid that does not dissolve or affect the material being screened. The liquid helps to break up the aggregates and keeps the particles from forming new aggregates. This liquid is removed before weighing.

(4) Comparison With Other Methods. It should be noted that the particle size of material passing through one sieve and retained on another is not the same as the arithmetic or geometric mean of the two sieves. Microscopic measurements of sieved fractions show that the average particle size determined microscopically is usually greater than the sieve values. When values obtained by the air permeability method are compared with the mean value of screened fractions, the air permeability values are considerably lower. The relationship between mean particle size data obtained on screens and data obtained by other means depends on the material being analyzed and the methods being compared.

b. Sedimentation

In place of microscopic measurements, sedimentation or elutriation procedures may be used to determine the average particle size distribution of powdered materials finer than 44 microns. Sedimentation procedures are usually preferred because a larger sample can be used. When analysis is conducted under standard conditions the results are reproducible.

(1) Assumption. Sedimentation procedures are based on the principle that particles settle because of gravitational forces. Because the downward acceleration is counterbalanced by frictional forces, each particle reaches its own terminal velocity. The resultant rate of fall is a function of the diameter and density of the par-

TABLE 3-2. RANGE OF STANDARD SIEVES

TYLER STANDARD SCREEN SCALE SIEVES
The W. S. Tyler Co., Cleveland, Ohio

Meshes per Lineal		Sieve Opening		Wire Diameter	
inch	cm.	inch	mm.	inch	mm.
2.5	0.98	0.312	7.92	0.088	2.24
3	1.18	0.263	6.68	0.070	1.78
3.5	1.38	0.221	5.61	0.065	1.65
4	1.57	0.185	4.70	0.065	1.65
5	1.97	0.156	3.96	0.044	1.12
6	2.36	0.131	3.33	0.036	0.914
7	2.76	0.110	2.79	0.0328	0.833
8	3.15	0.093	2.36	0.032	0.813
9	3.54	0.078	1.98	0.033	0.838
10	3.94	0.065	1.65	0.035	0.889
12	4.72	0.055	1.40	0.028	0.711
14	5.51	0.046	1.17	0.025	0.635
16	6.30	0.0390	0.991	0.0235	0.597
20	7.87	0.0328	0.833	0.0172	0.437
24	9.45	0.0276	0.701	0.0141	0.358
28	11.02	0.0232	0.589	0.0125	0.318
32	12.60	0.0195	0.495	0.0118	0.300
35	13.78	0.0164	0.417	0.0122	0.310
42	16.54	0.0138	0.351	0.0100	0.254
48	18.90	0.0116	0.295	0.0092	0.234
60	23.62	0.0097	0.246	0.0070	0.178
65	25.59	0.0082	0.208	0.0072	0.183
80	31.50	0.0069	0.175	0.0056	0.142
100	39.37	0.0058	0.147	0.0042	0.107
115	45.28	0.0049	0.124	0.0038	0.097
150	59.06	0.0041	0.104	0.0026	0.066
170	66.93	0.0035	0.089	0.0024	0.061
200	78.74	0.0029	0.074	0.0021	0.053
250	98.43	0.0024	0.061	0.0016	0.041
270	106.3	0.0021	0.053	0.0016	0.041
325	128.0	0.0017	0.043	0.0014	0.036

U. S. SIEVE SERIES

U. S. Bu. Standards, Standard Screen Series, 1919

Sieve No.	Meshes per Lineal: inch	Meshes per Lineal: cm.	Sieve Opening: inch	Sieve Opening: mm.	Wire Diameter: inch	Wire Diameter: mm.	% Tolerance in: Average Opening	% Tolerance in: Maximum Opening	% Tolerance in: Wire Diameter
2.5	2.58	1	0.315	8.00	0.073	1.85	1	10	5
3	3.03	1.2	0.265	6.73	0.065	1.65	1	10	5
3.5	3.57	1.4	0.223	5.66	0.057	0.45	1	10	5
4	4.22	1.7	0.187	4.76	0.050	1.27	1	10	5
5	4.98	2	0.157	4.00	0.044	1.12	1	10	5
6	5.81	2.3	0.132	3.36	0.040	1.02	1	10	5
7	6.80	2.7	0.111	2.83	0.036	0.92	1	10	5
8	7.89	3	0.0937	2.38	0.0331	0.84	2	10	5
10	9.21	3.5	0.0787	2.00	0.0299	0.76	2	10	5
12	10.72	4	0.0661	1.68	0.0272	0.69	2	10	5
14	12.58	5	0.0555	1.41	0.0240	0.61	2	10	5
16	14.66	6	0.0469	1.19	0.0213	0.54	2	10	5
18	17.15	7	0.0394	1.00	0.0189	0.48	2	10	5
20	20.16	8	0.0331	0.84	0.0165	0.42	3	25	5
25	23.47	9	0.0280	0.71	0.0146	0.37	3	25	5
30	27.62	11	0.0232	0.59	0.0130	0.33	3	25	5
35	32.15	13	0.0197	0.50	0.0114	0.29	3	25	5
40	38.02	15	0.0165	0.42	0.0098	0.25	3	25	5
45	44.44	18	0.0138	0.35	0.0087	0.22	3	25	5
50	52.36	20	0.0117	0.297	0.0074	0.188	4	40	10
60	61.93	24	0.0098	0.250	0.0064	0.162	4	40	10
70	72.46	29	0.0083	0.210	0.0055	0.140	4	40	10
80	85.47	34	0.0070	0.177	0.0047	0.119	4	40	10
100	101.01	40	0.0059	0.149	0.0040	0.102	4	40	10
120	120.48	47	0.0049	0.125	0.0034	0.086	4	40	10
140	142.86	56	0.0041	0.105	0.0029	0.074	5	60	15
170	166.67	66	0.0035	0.088	0.0025	0.063	5	60	15
200	200	79	0.0029	0.074	0.0021	0.053	5	60	15
230	238.10	93	0.0024	0.062	0.0018	0.046	5	60	15
270	270.26	106	0.0021	0.053	0.0016	0.041	5	60	15
325	323	125	0.0017	0.044	0.0014	0.036	5	60	15

BRITISH STANDARD SCREEN SCALE SIEVES
British Engineering Standards Association

Meshes per Lineal		Sieve Opening		Wire			Tolerance Average Aperture	Approx. Screening Area
				Diameter				
inch	cm.	inch	mm.	inch	mm.	Standard Gauge	±%	
5	1.97	0.1320	3.35	0.068	1.73	15.5	3	44
6	2.36	0.1107	2.81	0.056	1.42	17	3	44
7	2.76	0.0949	2.41	0.048	1.22	18	3	44
8	3.15	0.0810	2.06	0.044	1.12	18.5	3	42
10	3.94	0.0660	1.68	0.034	0.864	20.5	3	44
12	4.72	0.0553	1.40	0.028	0.711	22	3	44
14	5.51	0.0474	1.20	0.024	0.610	23	3	44
16	6.30	0.0395	1.00	0.023	0.584	23.5	3	40
18	7.09	0.0336	0.853	0.022	0.559	24	5	36
22	8.66	0.0275	0.699	0.018	0.457	26	5	36
25	9.84	0.0236	0.599	0.0164	0.417	27	5	35
30	11.81	0.0197	0.500	0.0136	0.345	29	5	35
36	14.17	0.0166	0.422	0.0112	0.284	31.5	5	36

BRITISH STANDARD SCREEN SCALE SIEVES

Meshes per Lineal		Sieve Opening		Wire			Tolerance Average Aperture	Approx. Screening Area
				Diameter				
inch	cm.	inch	mm.	inch	mm.	Standard Gauge	±%	
44	17.32	0.0139	0.353	0.0088	0.224	34.5	5	38
52	20.47	0.0116	0.295	0.0076	0.193	36	6	37
60	23.62	0.0099	0.251	0.0068	0.173	37	6	35
72	28.35	0.0083	0.211	0.0056	0.142	38.5	6	36
85	33.47	0.007	0.178	0.0048	0.122	40	6	35
100	39.37	0.006	0.152	0.004	0.102	42	6	36
120	47.24	0.0049	0.124	0.0034	0.086	43.5	6	35
150	59.06	0.0041	0.104	0.0026	0.066	45.5	8	37
170	66.93	0.0035	0.089	0.0024	0.061	46	8	35
200	78.74	0.003	0.076	0.002	0.051	47	8	36
240	94.49	0.0026	0.066	0.0016	0.041	48	8	38

ticle, and the density and viscosity of the suspending medium. For a spherical particle settling in a viscous medium, the diameter is given by Stokes' Law

$$d = \frac{18\mu V}{(D_1 - D_2)g}$$

where

d = particle diameter, cm

μ = viscosity of medium, poises

V = velocity of settling, cm/sec

D_1 = density of particle, gm/cc

D_2 = density of medium, gm/cc

g = acceleration of gravity, cm/sec^2

Because particles settle in a specific medium at a velocity proportional to their diameters, the concentration and size distribution in the medium will vary with time. If the concentration and weight of the particles can be. obtained as a function of time, a size distribution can be calculated.

Stokes' Law assumes a spherical particle, but because the particles in most powdered materials are not usually spherical in shape, it is customary to define a particle as having an "equivalent" or "Stokes" diameter. This is the diameter assigned to an irregular particle, which is equivalent to a spherical particle of the same density and falling at the same rate in the same medium.

Depending on the density of the granular material, the range of particle *sizes* considered optimum for sedimentation procedures is usually 2-50 microns. With coarse particles of a high density material the initial reading may occur too rapidly to obtain accurate times, whereas fine materials of low density may settle out so slowly that the evaluation becomes too time-consuming.

(2) Sources of Error. In all sedimentation procedures, one assumes that each particle will fall without interference. These procedures are subject to error because of poor or incomplete dispersion of the particles, reagglomeration of the particles, thermal gradients and turbulence in the suspending medium, too great a particle concentration, or the wall effect.

If the suspending medium is a liquid it must not react with the samples, and it should be sufficiently viscous to avoid turbulence, but not so viscous that the time of fall will be unduly prolonged. Often a small amount of a dispersing agent added to the liquid will aid in dispersion, which can be checked microscopically.

(3) Specific Techniques. Many sedimentation techniques for obtaining particle size data have been developed. Some of these devices are briefly described below.

(a) Divers

A series of small bulbs called divers is used to determine the specific gravity of the suspended sample. The distance the bulb falls in a selected time interval is used to calculate the settling time of a particle falling this distance. Because this method requires a large concentration of particles, agglomeration and particle interference may occur.

(b) Pipette

This widely used technique involves withdrawing a series of samples of a suspension at predetermined time intervals at a single fixed level. Each sample is evaporated to dryness and weighed to determine its concentration. From the results the percentage by weight of a particular range of particle size in the original sample is obtained.

Because a high concentration of sample is needed, problems of agglomeration and interference may arise. Moreover, accurate sampling is made difficult by the effects of variables such as the size of the tube used to withdraw samples and the speed with which the samples are withdrawn.

(c) Hydrometer

As with divers, the specific gravity of the suspension is determined. Samples of fixed volume are withdrawn at selected time intervals. From the specific gravity results are corrected to true readings to give the particle size. Agglomeration and particle interference may become problems.

(d) Manometer

As particles settle out of a suspending medium, the density of the suspension changes. These changes are the basis of this method, in which the settling tube is fitted with a capillary sidearm, containing a clear liquid, which serves as an inclined manometer. As the particles settle out, the density of the suspending medium decreases and the meniscus in the manometer recedes. Rate of this recession is used to determine particle size distribution in terms of Stokes' Law.

As with other sedimentation methods, problems of agglomeration and interference arise. Moreover, there is some flow of the clear liquid from the manometer into the sedimentation tube, creating convection currents that interfere with settling.

(e) Sedimentation balance

Another device for making particle size determinations is the sedimentation balance, which continually weighs the accumulation of particles as it settles out of the suspension. An automatic recording device or a lever arm with pointer and scale may be used. From weight versus time graphs, together with known data on rate of fall of particular particle sizes, particle size distribution data can be derived.

Serious disadvantages of this method are: (a) Inaccuracies of measurement arising from the gradual downward movement of the pan as particles accumulate in it (this movement causes convection currents in the suspension medium); (b) the need for a highly concentrated suspension, leading to agglomeration and interference; (c) the slowness of fall of the particles.

Sometimes a gas rather than a liquid is used as the suspending medium. This modification is generally an improvement, because the particles fall more rapidly and a longer sedimentation column can be used. One of the best known instruments of this type is the Sharples Micromerograph, which is described below.

The powder sample is projected into the instrument from the top through a powder feed system and deagglomerator. The particles fall through a settling column made of aluminum tubing. The particles fall at their terminal velocities until stopped by the pan of the servo-electronic balance at the bottom of the column. As the particles accumulate on the balance pan, a slight rotation of the balance beam on its torsion suspension occurs. A sensing device incorporated in the balance applies a signal to the electronic system of the instrument, which in turn applies a current to a restoring force coil on the balance beam. The current required to keep the beam balanced is a continuous measure of the accumulated weight of powder on the balance pan. A chart recorder makes a record of the accumulated weight versus time.

(f) Turbidimeter

The relationship between the turbidity of a fluid and its light-transmitting properties can be used for making particle size determinations. A beam of monochromatic light of known intensity in passed through a fluid in which a powdered sample is suspended, and the amount of scattered light is measured. The measurement is made at a fixed distance below the surface of the fluid and is repeated at predetermined time intervals, to secure 'data on the turbidity of the fluid at several stages of the settling process.

Although subject to some of the shortcomings of all sedimentation procedures--getting satisfactory dispersion, avoiding agglomeration, and so on--the turbidimeter is a convenient and relatively rapid method that gives reasonably accurate results. Only a small sample of moderate concentration is needed. This in itself minimizes problems of dispersion, interference, and agglomeration.

(g) Centrifuge

To speed up the rate of settling of small particles, centrifugal force is sometimes used. Differences between data obtained by centrifugation and data obtained when the particles are allowed to settle gravitationally have been studied, and the hypothesis has been advanced that when centrifugal force is used, the larger particles give impetus to the smaller ones, thereby distorting the sedimentation data. This effect is particularly important where a wide range of particle sizes is present.

c. Elutriation

Elutriation methods, unlike sedimentation methods where the particle moves in a still medium, use a moving medium.

By means of a vertically moving column of fluid, a powdered sample can be fractionated into several particle size categories. The fluid (usually a gas) is passed through the sample at various velocities and each velocity carries away and separates all particles whose terminal velocity of fall is less than the velocity of the moving air. The sample is constantly agitated to allow air to come in contact with all parts of it.

This method gives only general size distribution data, because size distribution within each fraction is not known. Moreover, at lower air velocities, the air flow is twice as rapid at the center of the tube as near the tube walls and this makes sharp separation impossible. A further limitation on its usefulness is that, for the smaller particles (under 5 microns), it takes too long (8 hours when 10% of the particles are under 5 microns) for separation to be effected. In general, elutriation methods suffer from the same sources of error as sedimentation procedures.

d. Air Permeability

The'rate of air flow through a bed of compressed particulate material can be used to determine the specific surface (area per unit weight) of that material. From the specific surface the mean surface particle size can be calculated. When either the desired specific surface or particle size distribution of a powdered material has been determined, the average particle size of this material, as determined by air permeability, can be used for control purposes.

This technique is rapid and reproducible and can be used for a variety of materials. Like other methods the particles are assumed to be spherical or essentially spherical in shape. Particle shapes such as flakes or needles give results that can be misleading.

(1) Procedure. Air is driven, at a fixed pressure, through a closed chamber (or cell) containing the compressed sample. The pressure drop across the cell is measured with a manometer and the rate of flow with a flowmeter.

Using a known weight and height of sample, the average particle size of the sample can be calculated from applicable equations. For determining the diameter of spherical or almost spherical particles, this method agrees well with microscopic measurement. (See Table 3-3.) Also, it is excellent for measuring specific surfaces up to about 10,000 sq cm per gram.

(2) Fisher Sub-sieve Sizer. The most widely used air permeability instrument is the Fisher Sub-sieve Sizer, described below. The practical limits for this apparatus is 2-50 microns.

The instrument uses the principle that a current of air flows more readily through a bed of coarse powder than through an otherwise equal bed of fine powder; i.e., equal in shape of bed and apparent volume. Investigators have standardized the conditions, thereby allowing the particle size to be obtained through the use of the instrument chart without mathematical computation.

The Sub-sieve Sizer is composed of an air pump, an air pressure regulating device, a precision bore sample tube, a standardized double range flowmeter, and a calculator chart. The air pump builds up air pressure to a constant head in the pressure regulator. The air, under this pressure head, is conducted to the packed powder sample contained in the sample tube. The flow of air through this packed bed of powder is measured by a calibrated flowmeter, the level of the fluid indicates directly on the chart the average diameter of the powder particle.

In practical use, the Fisher Sub-sieve Sizer offers a simple, rapid, and fairly reproducible means of determining the average particle size of powdered materials. A source of variation

TABLE 3-3. AGREEMENT OF FISHER SUB-SIEVE SIZER AND MICROSCOPE

	Atomized Aluminum			Potassium Perchlorate		
	Fine	Medium	Coarse	Fine	Medium	Coarse
Fisher Sub-sieve Sizer, average particle size, microns	5.0	14.0	39.0	3.0	11.0	24.0
Microscopic count, geometric mean diameter, microns	4.9	19.0	40.0	1.8	6.6	12.5

that may be encountered lies in obtaining reproducible manual packing of a sample to its minimum porosity in the sample tube. The principal limitation of the Fisher Sub-sieve Sizer is that no information is given on size distribution.

Good agreement between microscopic measurements and Fisher Sub-sieve Sizer determinations has been obtained for powders made up of spherical or almost spherical particles. Table 3-3 gives comparative results obtained for spherical atomized aluminum and irregularly shaped potassium perchlorate powders.

The average particle size value obtained by air permeability is biased to a smaller value because the finer particles present have the larger surface areas per unit weight of material.

The determination of average particle sizes between 100 and 500 microns can be made using a permeability apparatus larger than the Fisher Sub-sieve Sizer. This apparatus, which has been developed at Picatinny Arsenal, uses a sample size of approximately ten times the sample density.

e. Adsorption

The methods described to this point are based on the apparent dimensions and configuration of the particle. The presence of minute pores or crevices in the particle are not usually detected by these methods. When the presence of these irregularities is important they can be detected and measured by adsorption techniques from either the liquid or gas phase. The values obtained by these methods give the total surface available to the adsorbent.

(1) Liquid Phase. Some substances such as dyes and fatty acids in solution are readily adsorbed on the surfaces of powdered materials. An excess of a standardized solution of the adsorbent is added to the dry powder, and the unaffected adsorbent is determined by standard analytical procedures. Determinations are made at several different concentrations and the specific surface calculated from the amount adsorbed and the size of the molecule. This method is somewhat inaccurate because the solvent may also be adsorbed on the particles and interfere with the adsorbent. Another factor which leads to inaccuracies is the lack of precise data on the size of the molecule.

(2) Gas Phase. Gases are also adsorbed on the surface of powders and like the adsorption from the liquid phase can be used to calculate the specific surface and mean surface diameter of a powder. This method is more flexible inasmuch as various gases can be used and a wider range of surface areas can be measured. In principle the method consists of determining the amount of gas in a mono-molecular layer adsorbed on the surface of the powder. Plotting the moles of gas adsorbed per gram of solid against the equilibrium pressure at constant temperature an adsorption isotherm is obtained. From the graph the point on the graph corresponding to a monolayer of gas is determined and used to calculate the surface area of the powder.

f. Light Scattering

The average particle size of a sample can be obtained under certain conditions by measuring the intensity of the light scattered by the particles when suspended in a liquid. The procedure is often referred to as nephelometry. It is a useful technique for particles too small to measure by an optical microscope.

4. SAMPLING

The results obtained on a sample examined for average particle size, particle size distribution, or specific surface can only be as representative of the original material as the sample represents the original material. Because conclusions are drawn from a study of these Samples, and inferences concerning the properties and their effects on the behavior of the powders are made, it is important that the sample studied closely represent the original sample or sample lot. To be adequate, a sample must meet the following requirements:

1. It must be truly representative of the whole bulk of particulate material being examined; i.e., all particle sizes and shapes must be present in the same proportion in the sample as in the material being sampled.

2. It must be of a size suitable for examination and analysis by appropriate techniques for determining particle size and shapes. Subsampling is often necessary to reduce the sample to a usable size.

The sampling technique used depends on the type and amount of material to be analyzed. Samples of material can be obtained by:

1. Tumbling the sample container repeatedly until the enclosed sample is thoroughly mixed.

2. Fractionating the original sample with a riffle sampler.

3. Extracting the amount required for analysis, from the smallest working increment obtained, with a standard laboratory spatula or scoop.

The container is tumbled or rolled for 10 to 15 minutes prior to the actual sampling and allowed to set for at least five minutes to permit any fine dust particles present to settle. A closed sample thief is then inserted straight down into the powder until the tip of the thief reaches the bottom of the container. The thief is openedand twisted to make the powder pour into the sampler. The thief is then closed, so that the powder sample remains in the sampler, and the thief is extracted from the drum. Five or six such samples are taken; one from the center, and four or five from approximately equidistant points around the periphery.

The several samples are poured into a common container where they are reblended by thorough tumbling and, prior to subsequent analysis, resampled by means of the riffle sampler. This sampling technique is the most convenient method of obtaining small (less than 100 grams) representative samples of powdered materials from large, heterogeneous quantities.

Errors in the analysis, other than those introduced by sampling, can result from thefracturing of the particulate material during tumbling and sampling, from reagglomeration, and from the adsorption of moisture.

A master sample should be reservedfor future reference and analysis. It should be kept dry and should not be handled too frequently.

5. TREATMENT OF DATA

The data collected from a particle size analysis by count, size, or mass become more meaningful when reduced to disclose the type of distribution, average value, and dispersion. The normal or Gaussian distribution is seldom found in particle size analysis. Distributions are usually skewed with a sharp rise at the fine end of the distribution, followed by a tapering off at the coarse end.

The most common distribution found is the so-called log-probability type. This is treated most conveniently by placing the data on log-probability paper, on which the logarithm of the particle sizes is plotted against the cumulative frequency or weight of particles. If a straight line results, the distribution is log-normal. The average particle size (geometric mean) is found at the 50% point and the geometric standard deviation or dispersion is calculated from the ratio of the 84.13%/50% or 50%/15.87% values. The geometric standard deviation is useful in measuring the range of distribution, for 68% of all particles will have a size within the range

$$\frac{\text{geometric mean}}{\text{geometric standard deviation}}$$

to (geometric mean) (geometric standard deviation).

Sometimes a log-normal plot does not result in a straight line. The distribution may then be bimodal, or have two peak values. This would be shown on the graph as a sudden change in the slope of the line.

Another useful representation of the size data is the histogram. The percent of the total number is shown as a function of the size by a series of sequential parallelograms. The base of each parallelogram is determined by the selected size limits and the altitude by the percentage of particles falling within the size range. The histogram can be smoothed by drawing a curve through the midpoints of the rectangle tops.

The data may also be plotted as the cumulative frequency versus the micron size. This results in an "S" shaped curve, the slope of which depends on the distribution.

One of the advantages in using the probability graph method is the ease of conversion of particle size by count to particle size by weight or vice versa. If an approximately straight line on log-probability paper is obtained for one of these distributions, then the particle size in the material is distributed log normally. The other distribution will also be distributed log normally, with the same standard deviation, but about a different mean, Thus:

$$\begin{array}{c} \text{log geometric mean–} \\ \text{by count} \end{array} - \begin{array}{c} \text{log geometric mean} \\ \text{by weight} \end{array} - \begin{array}{c} \text{6.9 log2 geometric} \\ \text{standard deviation} \end{array}$$

Specific procedures for handling particle size data and discussions of average particle size and types of distributions and their evaluation will be found in the references.

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This listing is intended to supplement MIL-STD-444, Military Standard Nomenclature and Definitions in the Ammunition Area. Listing of Ordnance Terms and Abbreviations, prepared by the U.S. Naval Ammunition Depot, Crane, Indiana, and Special Text ST 9-152, Ordnance Technical Terminology, printed by the U.S. Army Ordnance School, Aberdeen Proving Ground, Maryland, have also been consulted. Terms given here are not intended for mandatory use, but are included to help readers of this handbook.

ABSORPTION. The talking up of a gas, light, heat, or liquid by a substance.

ACCELERATION. Change of velocity with respect to time. Dimensions (length/time^2).

ACCELERATOR. A substance added to speed up a chemical reaction.

ACTIVATION ENERGY. The energy difference (E) between an active and a normal molecule, acquired as a result of interchanges occurring in collisions, which allow the molecule to take part in chemical or physical reactions; obtained from Arrhenius type relationships such as that between the log of the specific reaction rate (K) and the reciprocal of the absolute temperature (T), ($K = A^{-E/RT}$), where A is, a frequency factor or entropy term, and R is the universal gas constant.

ADDITIVE. Any material added to a mixture to modify some physical or chemical property of that mixture (rate of reaction, consistency, stability, structural strength).

ADIABATIC TEMPERATURE. The temperature attained by a system undergoing a volume or pressure change in which no heat enters or leaves the system.

ADSORPTION. The adhesion in an extremely thin layer of the molecules of gases, of dissolved substances, or of liquids to the surfaces of solid bodies with which they are in contact.

AEROSOL. Fine particles of solid or liquid suspended in air. Recently used to denote almost any dispersion in air. Technological interest, however, has been largely confined to particle sizes within the range of 0.1 to 100 microns diameter.

AGGLOMERATION. The property of particles to cohere, thereby increasing apparent particle size.

AMBIENT. Surrounding meteorological conditions such as ambient temperature, humidity, and pressure.

AMMUNITION. 1. All bullets, projectiles, rockets, grenades, torpedoes, bombs, and guided missiles with their necessary propellants, primers, fuzes, detonators, and charges of conventional explosive, nuclear explosive, chemical, or other materials. 2. In the broadest sense the term is not limited to materials used against an enemy, but includes all explosives, explosive devices, pyrotechnics, and pyrotechnic devices. Ammunition may be used for illumination, signaling, saluting, mining, digging, cutting, accelerating, decelerating, catapulting personnel or materiel, operating or stopping mechanisms, demolition, decoying, practice, training, guarding, game hunting, and pure sport. 3. In the most restricted sense the term includes a complete round and all its components; that is, the material required for firing a weapon such as a pistol, rifle, or cannon, from which a projectile is thrown. Generally the term is used or taken in its broadest sense (sense 2) unless a more restricted sense is indicated or is implied.

ANTIAGGLOMERANT. An additive used to prevent clustering or cohesion of particles.

APPARENT DENSITY. The ratio of mass to volume of a finely powdered material, under stated conditions, which is always less than true density. Sometimes called loading density. Because apparent density depends on the method used to obtain it, the method should always be specified. See BULK DENSITY.

ARM. To make ammunition ready for functioning, as by removal of safety devices or alignment of the elements in the explosive train of the fuze.

ARMING DEVICE. A safety device that prevents a fuze from functioning or being in readiness to function until a selected interval has elapsed. Often called a safety and arming (S & A) device.

ARRHENIUS EQUATION. Represents the influence of temperature upon the rate of chemical reaction. $K = e^{-E/RT} +$ constant. Where $e = 2.718$, E is activation energy, K is the specific reaction rate, R is the gas constant, and T is absolute temperature.

ASH. Combustion products, usually in the form of slag or crust, accumulating at the surface, along the cavity wall, and immediately beyond the flame area, which tend to interfere with combustion and visibility of the flame or colored smoke or pyrotechnic ammunition.

ATOMIZED. Reduced to fine particles, essentially spherical.

ATTENUATION. The lessening of any signal or effect, such as sound or light, with respect to time or distance.

AUXILIARY PARACHUTE. A parachute that augments or initiates the operation of the main parachute.

AVERAGE BURNING RATE. The arithmetic mean (statistical average) burning rate of pyrotechnic or explosive mixtures at specific pressures and temperatures. Dimension (length/time or mass/time).

BALLING. A method of preparing relatively uniform powder size in the form of balls.

BALLISTICS. The science of the propulsion, flight, and fragmentation of projectiles and missiles. Exterior ballistics deals with the forces on projectiles while in flight; interior ballistics deals with the forces of projectiles in a gun or the reaction that takes place within the motor of a rocket; terminal ballistics deals with the effect of projectiles or missiles on a target at the time of bursting or at the end of their trajectory.

BARATOL. An explosive composed of barium nitrate and TNT. Baratol, which is less brisant than TNT, is used as burster charge for colored marker projectiles.

BARRICADE. A structure, shield, or mount to protect personnel, equipment, or facilities. Used to deflect or confine the blast or fragmentation effects of explosives or deflagrations. A barricade is used during loading and testing of explosives and pyrotechnics.

BARRIER. A material designed to withstand penetration of bullets, shell fragments, sparks, or water, oils, moisture, or heat.

BASE EJECTION. A projectile that ejects its content$ from its base. Usually the ejecting force is an expelling charge, actuated by a fuze. Various special purpose projectiles such as illuminating, leaflet, and some smoke projectiles, are of the base ejection type. See CHARGE; EXPELLING; EJECTION.

BASE IGNITION. A signal or other munition that ignites from the base with subsequent emission of smoke or chemical.

BASE PLATE. A metal plate covering the base of a projectile.

BASING, TRACER BULLET. Bullet basing is turning the periphery of the cylindrical base end of thin section bullet jackets toward the center of the cavity to produce a predetermined radius and restriction at the open rear end of the bullet.

BEE HIVE. A temporary storage building for explosives. The name arises from its shape. See also DOG HOUSE; IGLOO.

BICKFORD FUSE. A safety fuse having a core of black powder enclosed within a tube of woven threads, surrounded by various layers of waterproof textile for sheathing. The fuse burns at specific rates.

BINDER. Compositions that hold together a charge of finely divided particles, and increase the mechanical strength of plugs or pellets of these particles when consolidated under pressure. Binders usually are resins, plastics, asphaltics, or hard waxes used dry or in solution.

BLACKBODY. Any object that completely absorbs all radiation incident upon it, or conversely, a body that at any given temperature radiates maximum possible energy.

BLACK POWDER. A low explosive consisting of an intimate mixture of potassium or sodium nitrate, charcoal, and sulfur. It is easily ignited and is friction sensitive. Formerly used as a propellant, but now used almost exclusively in propellant igniters and primers, in fuzes to give short delays, in blank ammunition, and as spotting charges in practice ammunition. See MEAL POWDER.

BLAST. Specifically, the brief and rapid movement of air or other fluid away from a center of outward pressure, as in an explosion; the pressure accompanying this movement. This term is also commonly used as the equivalent of "explosion," but the two terms may be distinguished.

BLASTING CAP. A small thin-walled cylindrical case containing a sensitive explosive, such as lead azide. Used as a detonator to set off another explosive charge. The explosive in the blasting cap is fired either by a burning fuse or by electricity. Also called a DETONATOR, which see.

BLIND. A fired tracer round that does not ignite in the gun, and which shows no visible trace over any part of the trajectory.

BLOWBACK. (Primer) The release of initiation products away from the intended direction.

BLOWBY. The bypassing of one element in an explosive train.

BOMB. In a broad sense, an explosive or other lethal agent, together with its container or holder, which is designed to be dropped from an aircraft. In a pyrotechnic sense bombs can be classified as follows: Atomic simulator bomb. A pyrotechnic bomb used to simulate an atomic bomb for training purposes. Closed bomb. A test device used to evaluate the thermochemical characteristics of combustible materials. Also called a "closed chamber." The closed bomb is a thick walled, alloy steel cylinder with a removable threaded plug in each end. One plug contains the ignition system, the other plug is used to record pressure-time data. The bomb is cooled by a water jacket. The closed bomb is used to determine the linear burning rate, relative quickness, and relative force, under varying conditions of pressure and temperature of propellants. Fire or incendiary bomb. An item designed to be dropped from an aircraft to destroy or reduce the utility of a target by the effects of combustion. It contains an incendiary mixture that spreads on impact to burn or envelope in flames any material targets. When empty or inert loaded an incendiary bomb may be used for training purposes. Example: BOMB, FIRE: 750-lb, M116A1; BOMB, FIRE: 750-lb, MK 77 Mod O. BOMB, INCENDIARY: 4-lb, TH3, AN-M50A3. Napalm bomb. A fire bomb filled with napalm, a thickened petroleum oil. Primarily an antipersonnel weapon and often distinguished from an incendiary bomb, which is used primarily against installations or materiel. Phosphorus bomb. A smoke bomb filled with phosphorus, .especially white phosphorus. Photoflash bomb. A bomb containing photoflash mixture. It is designed to function at a predetermined distance above the ground, to produce a brilliant light of short duration for photographic purposes. Example: BOMB, PHOTOFLASH: M122 (w/o burster); BOMB, PHOTOFLASH: 100lb, AN-M46; BOMB, PHOTOFLASH: 150-lb, M120A1; BOMB, PHOTOFLASH: 150-lb, empty, M120. Target identification bomb. An aerial bomb that, upon impact, produces a relatively prolonged and conspicuous effect, such as a bright colored light, which provides a means of locating and identifying the target by other aircraft. Example: BOMB, TARGET IDENTIFICATIONS: SMOKE, MK72 Mod O. Unexploded bomb. A bomb that fails to explode on impact or immediately thereafter. It is considered to be a delayed action bomb until the contrary is proved.

BOOM POWDER. A pyrotechnic ignition mixture designed to produce many incandescent particles. A typical boom composition is:

Ingredient	Parts by Weight
Iron Oxide	50
Titanium (powdered)	32.5
Zirconium (powdered)	17.5

plus about 1 part of cellulose nitrate as a binder.

BOOSTER. 1. An assembly of metal parts and explosive charge provided to augment the explosive component of a fuze, to cause detonation of the main explosive charge of the munition. May be an integral part of the fuze. The explosive in the booster must be sensitive enough to be actuated by the small explosive elements in a fuze, and powerful enough to cause detonation of the main explosive filling. 2. An auxiliary propulsion system, employed in the early launching phase of a missile, used in addition to the principal propelling means. It may be released from the missile when its impulse has been delivered.

BRIGHTNESS. The luminous intensity (I) of any surface (a) in a given direction per unit of projected area of the surface as viewed from that direction; expressed as $B = \frac{dI}{da} (\cos \theta)$, where θ is the angle between the direction of observation and the normal to the surface.

BRIGHTNESS PYROMETER. A photoelectric device for measuring brightness.

BRISANCE. The shattering ability of explosives, usually measured in amount of sand crushed in a closed, heavy walled container.

BULK DENSITY. The mass per unit volume of a bulk material such as grain, cement, coal. Used in connection with packaging, storage, or transportation. A commercial rather than a laboratory term. See APPARENT DENSITY.

BURNING. A rapid evolution of energy through chemical reaction between a fuel and an oxidizing agent. See COMBUSTION. Burning rate is the rate of propagation of a pyrotechnic mixture. The burning time is the time elapsed between initiation and completion of reaction of a pyrotechnic mixture. Burning time depends on many factors such as length of column, degree of consolidation, temperature, pressure, percentage of ingredients and their particle size.

BURST. Explosion of a munition.

BURST ALTITUDE. Height at which a munition functions or is designed to function.

BURST DURATION. The time of persistence of a cloud of burning incandescent particles.

BURST, TRACER. A pyrotechnic composition that explodes inside a projectile cavity with a loud report or a large flash at some point along the trajectory after leaving the gun barrel.

BURSTER. An explosive charge used to break open and spread the contents of projectiles, bombs, or mines. Syn. Burster charge.

BURSTER TUBE. The tube that holds the burster in a chemical projectile.

BUTTER. To apply a paste-like mixture with a spatula or knife.

CALCINED. Reduced to a powder by the action of heat. To expel volatile matter.

CANDLE. 1. An item or that portion of an item which, by its progressive combustion, produces smoke or light over a comparatively long period of time. 2. The unit of luminous intensity. The unit used in the United States is a specified fraction of the average horizontal candlepower of a group of 45 carbon-filament lamps preserved at the National Bureau of Standards, when the lamps are operated at specified voltages. This unit is identical within the limits of uncertainty of measurement, with the International Candle established in 1909 by agreement among France, Great Britain, and the United States and adopted in 1921 by the International Commission on Illumination.

The international agreement of 1909 fixed only the unit at low color temperatures as represented by carbon-filament lamps. In rating lamps at higher temperatures, differences developed between the units used in different countries. In 1937 the International Committee on Weights and Measures adopted a new system of units based upon (1) assigning 60 candles per square centimeter as the brightness of a blackbody at the temperature of solidifying platinum, and (2) deriving values for standards having other spectral distributions by using accepted luminosity factors.

CANDLEPOWER. (cp) The luminous intensity (I) expressed in candles, when F is luminous flux, and W is the solid angle in steradians. $I = \frac{dF}{dW}$

CANDLESECOND. A measure of total luminous energy transmitted when a source of luminous intensity of one candle acts for one second.

CANISTER. An inner container or cylinder in a projectile containing materials for special terminal effects, such as smoke, propaganda leaflets, chaff, or metal fragments. The container is designed to open up at some predetermined point after launching. Example: CANISTER, SMOKE: 5-INCH PROJECTILE; WP M5; CANISTER, SMOKE: 105-MM PROJECTILE, HC, M1; CANISTER, SMOKE: 155-MM PROJECTILE, GREEN, M3.

CARTRIDGE. An explosive item designed to produce gaseous products of combustion under pressure, for performing a mechanical operation other than the common one of expelling a projectile. A photoflash cartridge is a cartridge used for making aerial photographs from low altitudes during reconnaissance missions. Consists of a photoflash charge and delay fuze, and is assembled in a primed cartridge case together with a small propelling charge. Example: CARTRIDGE: PHOTOFLASH: M112 or M112A1, 1-sec delay; CARTRIDGE, PHOTOFLASH: M112 or M112A1, 4-sec delay. A practice photoflash cartridge is a cartridge used for training purposes, to simulate release and firing of photoflash cartridges. Example: CARTRIDGE: PHOTOFLASH, PRACTICE: M124. A signal practice bomb cartridge is an explosive inserted in the nose of a practice bomb. It is detonated upon impact and produces a puff of white smoke. Example: CARTRIDGE, SIGNAL, PRACTICE BOMB: MK6 Mod O, w/fuze, MK247 Mod O; CARTRIDGE, SIGNAL, PRACTICE BOMB: AN-MK4 Mod 1; CARTRIDGE, SIGNAL, PRACTICE BOMB: miniature, MK5 Mod O.

CASE. A box, sheath, or covering used to house ordnance materials.

CASTING. The procedure for loading molten charges into a container, and allowing to harden. See MELT LOADING.

CATALYST. 1. A substance that alters the rate of a reaction, but may be recovered unaltered at the end of the reaction. 2. A promoter used in plastics.

CAVITY. (Cavitation) An air space within mixtures that usually results in nonuniform burning or premature bursting.

CAVITY GEOMETRY. Specifically, those dimensions that affect the performance characteristics of a pyrotechnic or smoke composition, such as length, diameter, effective area, and configuration.

CHARGE, EXPELLING. Small charge of black powder or other low explosive in a base ejection projectile to eject contents, such as smoke canisters from the projectile. See BASE EJECTION.

CHARGE, FLASH. 1. A readily ignitible explosive charge used in ignition elements of electric primers and detonators. It usually ignites a subsequent charge of lesser sensitivity and greater brisance. 2. Pyrotechnic charge used in flash producing items such as photoflash cartridges, bombs, or spotting devices. See PHOTOFLASH COMPOSITION.

CHARGE, SHAPED. An explosive charge with a shaped cavity so that the explosive energy is focused to move in one direction. Sometimes called "cavity charge." Called "hollow charge" in Great Britain. Use of the term shaped charge generally implies the presence of a lined cavity.

CHARGE, SIGNAL, EJECTION. An explosive device designed to eject a signal from an underwater mine when used for training, Example: CHARGE, SIGNAL, EJECTION: MK3 Mod O.

CHARGE, SPOTTING. See SPOTTING CHARGE.

CHEMICAL AGENT. A substance used for riot control, incapacitating or casualty effect. Smokes and incendiaries are also classified as chemical agents.

CHEMICAL AMMUNITION. Any ammunition containing casualty agents, riot control agents, incendiaries, and burning-type signaling or screening smoke mixtures as the primary filler.

CHIMNEY EFFECT. The characteristic of hot gases to rise rapidly prior to any horizontal motion. In smoke producing munitions, when hot ashes accumulate at the signal orifice and cause flaming of the smoke producing products this condition is sometimes referred to as chimney effect. For flares, when a flare case is unconsumed during burning obscuring part of the light produced and reducing its luminosity, this undesirable condition is also referred to as chimney effect.

CIE SCALE. Formerly known as the ICI scale. A scale of color values developed by the "Commission Internationale de l'Eclairage," (CIE), International Commission on Illumination (ICI).

CIGARETTE BURNING. In rocket propellants, black powder, gasless elements, and pyrotechnic candles, the type of burning induced in a solid grain by permitting burning on one end only, so that the burning progresses in the direction of the longitudinal axis.

CLOUD. See SMOKE.

CLUSTER. 1. A collection of small bombs held together by an adapter for dropping. A cluster of fragmentation bombs so arranged that more than one bomb can be suspended and dropped from a single station of an airplane bomb rack. 2. A pyrotechnic signal consisting of a group of stars.

COLOR BURST UNIT. A unit containing a dye material placed in the nose of target projectiles, which produces a distinguishing color upon functioning of the fuze.

COLOR CHARTS. Charts used as standards to determine colors both as to hue and tone. Charts commonly used are Munsell, Chroma, and CIE.

COLORED SMOKE. Products of a distinctive color formed by either volatilization and condensation or combustion. The basis for a colored smoke is a volatile dye, which upon condensing forms a colored cloud. The dye may be volatilized by explosion of a burster charge, as in a colored marker projectile or by combustion of a fuel mixed with the dye, as in a colored smoke candle. Colored smoke munitions are made in several forms, including projectiles, bombs, grenades, and candles. They may be used as signals, target markers, and zone identification markers. The most satisfactory smoke colors are red, green, yellow, and violet.

COLOR INTENSIFIER. A halogenated compound added to flare compositions that makes flame colors more saturated.

COLOR PERCEPTION. The ability to distinguish among color hues.

COLOR RATIO. 1. A number that designates both hue and tone. 2. The proportion of visible radiation of a specific wavelength to the total visible radiation; also called color value,

COLUMN LENGTH. The length of an explosive or pyrotechnic composition.

COMBUSTIBILITY. Capability of burning. Flammable. The relative combustibility of materials in storage is defined as: Hazardous--materials that by themselves or in combination with their packaging, are easily ignited and will contribute to the intensity and rapid spread of a fire. Moderate--materials and their packaging both of which will contribute fuel to a fire. Low--materials that will not normally ignite, but which, in combination with their packaging, will contribute fuel to a fire. Noncombustible--materials and their packaging that will neither ignite nor support combustion.

COMBUSTION. A continuous, rapid chemical process accompanied by the evolution of energy, commonly the union of a fuel and an oxidizing agent. See BURNING.

COMPATIBILITY. Ability of materials to be stored intimately without chemical reaction occurring. Incompatibility may result in loss of effectiveness, or may be very hazardous.

COMPOSITION, PYROTECHNIC. A physical mixture of finely powdered fuel and oxidant, with or without additives, to produce a desired effect.

CRIMP. To put a bend or crease in metal, often used as a method of sealing or fastening two pieces of metal together. A cartridge case is crimped to a projectile.

CRITICAL HUMIDITY. The humidity at which the material is in equilibrium with its environment with respect to moisture content.

CURE TIME. Time required for polymerization of certain plastic materials to achieve a certain structural strength or surface hardness.

DARK IGNITER. Tracer that has period of darkness between ignition and visible flame (British). **2.** Igniter for tracer with low luminous intensity to prevent blinding of the gunner. See DIM IGNITER.

DEACTIVATE. The act of rendering an explosive device inert or harmless.

DEAD-LOAD. Total pressure in pounds used to consolidate pyrotechnic compositions.

DEAD PRESSED. In an explosive, a highly compressed condition which tends to prevent the transition from deflagration to detonation that would otherwise take place.

DECOMPOSITION. The process of breaking down a material into more simple products. Disintegration, dissociation.

DEFLAGRATION. Very rapid combustion sometimes accompanied by flame, sparks, or spattering of burning particles. Qeflagration, although classed as an explosion, generally implies the burning of a substance with self-contained oxygen so that the reaction zone advances into the unreacted material at less than the velocity of sound in the unreacted material. The term is often used to refer to the action of a high explosive projectile that upon impact with a target does not produce the usual effects of a high-order detonation. Strictly speaking, the term low-order detonation should be used to describe such a phenomenon if it is intended to connote a detonation at lower than the stable detonation velocity of the explosive. The term deflagration should be used if it is intended to connote a burning reaction. See EXPLOSION.

DEGRESSIVE BURNING. Propellant granulation in which the surface area of a grain decreases during burning. The degressive burning of a propellant is sometimes termed degressive granulation or regressive burning. See PROGRESSIVE BURNING.

DELAY. A pyrotechnic, mechanical electronic, or explosive train component that introduces a controlled time delay in some element of the arming or functioning of a fuze mechanism.

DELAY, ARMING. 1. The time or distance interval between the instant a piece of ammunition carrying the fuze is launched and the instant the fuze becomes armed. **2.** The time interval required for the arming processes to be completed in a nonlaunched piece of ammunition. See DELAY.

DELAYED. When the term is used in connection with tracer bullet observation, it means that the bright trace starts late along the trajectory, but traces at least the minimum distance required.

DELAY ELEMENT. An explosive train component normally consisting of a primer, a delay column, and a relay detonator or transfer charge assembled in that order in a single housing to provide a controlled time interval.

DELAY, FUNCTIONING. The time or distance interval between initiation of the fuze and detonation of the bursting charge. See DELAY.

DELAY, GASLESS. Delay elements consisting of a pyrotechnic mixture that burns without production of gases.

DELAY IGNITER. A delay element used in conjunction with ignitible materials; such as igniter composition for tracer bullets. Delay igniters are designed to produce no visible exterior burning for a predetermined distance of the initial portion of the trajectory.

DENSITY OF CHARGE. The weight of pyrotechnic charge per unit volume of the chamber, usually expressed in grams per cubic centimeter.

DESICCANT. A drying agent.

DETONATE. To be changed by exothermic chemical reaction usually from a solid or liquid to a gas with such rapidity that the rate of advance of the reaction zone into the unreacted material exceeds the velocity of sound in the unreacted material; that is, the advancing reaction zone is preceded by a shock wave. See DETONATION.

DETONATING AGENT. Explosive used to set off other less sensitive explosives. Includes initial detonating agents, and other less sensitive explosives that may be used as intermediate explosive elements in a detonating train.

DETONATING CORD. A flexible fabric tube containing a filler of high explosive initiated by a blasting cap or electric detonator.

DETONATION. (Detonation Rate, Detonation Velocity) An exothermic chemical reaction that propagates with such rapidity that the rate of advance of the reaction zone into the unreacted material exceeds the velocity of sound in the unreacted material; that is, the advancing reaction zone is preceded by a shock wave. A detonation is an explosion. The rate of advance of the reaction zone is termed detonation rate or detonation velocity. When this rate of advance attains such a value that it will continue without diminution through the unreacted material, it is termed the stable detonation velocity. The exact value of this term depends upon a number of factors, principally the chemical and physical properties of the material. When the detonation rate is equal to or greater than the stable detonation velocity of the explosive, the reaction is a high-order detonation. When the detonation rate is lower than the stable detonation velocity of the explosive, the reaction is a low-order detonation. See DETONATE; DETONATION WAVE; EXPLOSION.

DETONATION WAVE. The shock wave that precedes the advancing reaction zone in a high-order detonation. See DETONATION.

DETONATOR. 1. In an explosive train, that component which, when detonated by the primer in turn detonates a less sensitive explosive (usually the booster), or when containing its own primer, initiates the detonation in the train. A detonator can be activated by either an explosive impulse (a primer) or a nonexplosive impulse. When activated by a nonexplosive impulse, the detonator contains its own primer. Detonators are generally classified as percussion, stab, electric, or flash, according to the method of initiation. 2. An explosive charge placed in certain equipment and set to destroy the equipment under certain conditions. Preferred term in this sense is DESTRUCTOR, EXPLOSIVE.

DICHROMATION. A chemical treatment employing salts of chromium to metals or alloys to inhibit corrosion.

DILUENT. An additive, usually inert, used to regulate burning rate or temperature.

DIM IGNITER. Igniter composition for tracer bullets designed to produce weak or dimly visible trace, visible to gunner for a predetermined distance of the initial portion of the trajectory. See DARK IGNITER.

DISC, BLOWOUT. A thin, metal diaphragm, sometimes installed in a rocket motor as a safety measure against excess gas pressure.

DISPERSING AGENT. A surface active agent that tends to keep solid particles dispersed in a liquid medium.

DOG HOUSE: A small temporary storage space for explosives. See also BEE HIVE; IGLOO.

DRY BLEND. A mixture of dry powders.

DUD. An explosive munition that fails to explode although such was intended.

DWELLTIME. In press loading powders into cavities, the interval of time that the powder is held at the full loading pressure.

EFFICIENCY. Ratio of the actual performance of an operation to the ideal performance, often expressed as a percentage.

EJECTION. The throwing out of loose material or a canister from a munition, usually by an expelling charge; may occur after impact or at any preset altitude. See BASE EJECTION.

ELECTROSTATIC SENSITIVITY. See SENSITIVITY.

ELUTRIATION. The process of purifying by washing and straining or decanting.

EMISSION. Flow of electrons out of heated materials.

EMISSIVITY. The rate at which a solid or a liquid emits electrons when additional energy is imparted to the free electrons in the material by the action of heat, light, or other radiant energy or by the impact of other electrons on the surface.

EMITTERS. The component of a pyrotechnic flash or flame responsible for the development of the color.

END ITEM. An item developed to meet a stated requirement. Usually a combination of components, assemblies, or parts ready for their intended use, and not a component of a larger assembly.

ENDOTHERMAL. A reaction that occurs with the absorption of heat. Opposed to exothermal.

ENSIGN-BICKFORD FUSE. A powder train encased in a cotton or plastic sheath. See FUSE, BICKFORD.

ENTHALPY. A concept for any system defined by $H = E + PV$, where H is enthalpy, E is internal energy, P is pressure, and V is the volume. Often called the total heat. Change in enthalpy is the amount of heat added to, or subtracted from, a system in going from one state to another under constant pressure.

ENTROPY. The degree in which the energy of a system has ceased to be available. $dS = \frac{dQ}{T}$, where S is entropy, Q is heat absorbed by a system, and T is absolute temperature.

ENTROPY OF ACTIVATION. Related to the probability of the activated state (P), which is the essential intermediate in all reactions. $PZ = e^{ASR}$ (KT/h) where S is entropy, R is the gas constant, and Z and KT/h are essentially constant.

EQUATION OF STATE. Any of several equations relating the volume, temperature, and pressure of a system.

EXOTHERMAL. A process characterized by the evolution of heat. Opposite of endothermal.

EXPLODE. To be changed in chemical or physical state usually from a solid or liquid to a gas (as by chemical decomposition or sudden vaporization) so as to suddently transform considerable energy into the kinetic form, See EXPLOSION.

EXPLOSION. A chemical reaction or change of state that is effected in an exceedingly short space of time with the generation of a high temperature and generally a large quantity of gas. An explosion produces a shock wave in the surrounding medium. See DEFLAGRATION.

DETONATION. A confined explosion is an explosion occurring, as in a closed chamber, where the volume is constant. An unconfined explosion is an explosion occurring in the open air where the (atmospheric) pressure is constant.

EXPLOSION PROOF. Equipment and components constructed so that either they will not spark or that dusts and vapors are barred from places where sparking does occur.

EXPLOSIVE. A substance or mixture of substances that may be made to undergo a rapid chemical change, without an outside supply of oxygen, with the liberation of large quantities of energy generally accompanied by the evolution of hot gases. Explosives are divided into two classes: high explosives and low explosives, according to their rate of reaction in normal usage. Certain mixtures of fuels and oxidizers can be made to explode and are considered to be explosives. However, a substance such as a fuel, which requires an outside source of oxidizer, or an oxidizer, that requires an outside source of fuel to explode, is not considered an explosive.

EXPLOSIVE, CONVENTIONAL. A nonatomic explosive.

EXPLOSIVE FILLER. Main explosive charge contained in a projectile, missile, bomb, or the like. See CHARGE, as modified.

EXPLOSIVE LIMIT. Maximum weight of explosive that may be allowed in any particular storage, loading, or handling area.

EXPLOSIVE TRAIN. A train of combustible and explosive elements arranged in order of decreasing sensitivity inside a fuze, projectile, bomb, gun chamber, or the like. The explosive train accomplishes the controlled augmentation of a small inpulse into one of suitable energy to actuate main charge of the munition. A fuze explosive train may consist of a primer, a detonator, a delay, a relay, a lead and booster charge, one or more of which may be either omitted or combined. If the bursting charge is added to the foregoing train it becomes a bursting charge explosive train. A propelling charge explosive train might consist of a primer, igniter or igniting charge, usually black powder, and finally, any of the various types of propellants. See LEAD, EXPLOSIVE.

FILLER. 1. An ammunition charge. 2. An inert additive.

FILTERING. Undesirable loss of smoke density and hue due to ash formation causing degradation of the dye.

FILTER (OPTICAL). A type of optical equipment that will transmit or absorb light of a certain range of wavelengths.

FIRECRACKER. A small paper cylinder containing an explosive and a fuse. It is used to simulate the noise of an explosive charge.

FIRST FIRE. The igniter composition used with pyrotechnic devices that is loaded in direct contact with the main pyrotechnic charge. A pyrotechnic first fire composition is compounded to produce a high temperature and hot slag. The composition must be readily ignitible, and capable of igniting the underlying pyrotechnic charge. See also STARTING MIX; IGNITER.

FISSURES. Cracks in pressed or cast pyrotechnic mixtures, which are undesirable because they increase burning areas and rates, and can affect physical characteristics.

FLAKES. Extremely thin, small particles of metal.

FLAME. 1. A chemical reaction or reaction product, partly or entirely gaseous, that yields heat and light. 2. State of blazing combustion. A flame profile is a temperature profile of any particular flame. Flame temperature is the calculated or determined temperature of the flame.

FLAMING. Production of a flame that is undesirable in compositions designed for dissemination.

FLARE. A pyrotechnic munition designed to produce a single source of intense light for relatively long durations for target or airfield illumination, signaling, or other purposes. An aircraft flare is a pyrotechnic munition designed for use from aircraft. Produces a single source of intense light for signaling, target, or airfield illumination. Example: FLARE, AIRCRAFT; guide, red, T7E1; FLARE, AIRCRAFT; guide, white, T3. An airport flare is a pyrotechnic munition designed to identify and illuminate an airport in the absence of other illumination. A chute flare is a popular name for parachute attached to a flare. Float flare is a signal launched from aircraft, to mark a location at sea. It floats on the surface and emits smoke and flame for up to an hour. Guide flare is an electrically ignited aircraft flare for attachment to an aerial bomb, which produces very bright light, either white or colored, to mark the position of the bomb and permit its guidance to the target. An illuminating flare is any pyrotechnic device that produces a brilliant, single source light of relatively long duration. A surface flare is a pyrotechnic item designed for use in surface positions, ground or water. Produces a single source of intense light for illumination of airport runways, warning of infiltrating enemy troops, and other purposes. Example: FLARE, SURFACE: airport, M76; FLARE, SURFACE: float, MK15 Mod O; FLARE, SURFACE: trip, M49; FLARE, SURFACE: trip, parachute, M48; FLARE, SURFACE: trip wire, MK1 Mod O. A trip flare is a surface flare actuated by, and thus serving as a warning of the approach of, infiltrating enemy troops. It is booby trapped and in one type is attached to a parachute that is projected into the air.

FLARE, GUIDED MISSILE. A pyrotechnic device that produces an intense light for the purpose of visually tracking a guided missile during its flight to a target. Excludes TRACER, GUIDED MISSILE.

FLARE MIXTURE. A pyrotechnic composition, compounded to produce a brilliant light of relatively long duration, either white or colored.

FLARE, PARACHUTE. Any flare attached to a parachute and designed to provide intense illumination. Used to light targets for night bombing, for reconnaissance, or to furnish light for aircraft emergency landings. A hand fired parachute flare is a complete self-contained device fired from the hand, and which provides a rocket projected, parachute borne, pyrotechnic light.

FLASH. Indicates in the case of simulators and other pyrotechnic items, that item is intended to produce a flash.

FOOT CANDLE. The unit of illumination when the foot is taken as the unit of length. It is the illumination on a surface one square foot in area on which there is a uniformly distributed flux of one lumen, or the illumination produced at a surface all points of which are at a distance of one foot from a uniform point source of one candle.

FORMULATION. A pyrotechnic composition. See COMPOSITION, PYROTECHNIC.

FUEL. 1. Any substance used to produce heat by burning. 2. A combustible material used in pyrotechnic composition, for example, powdered metals and resins.

FUSE. (Not to be confused with FUZE.) An igniting or explosive device in the form of a cord, consisting of a flexible fabric tube and a core of low or high explosive. Used in blasting and demolition work, and in certain munitions. A fuse with a black powder or other low explosive core is called a "safety fuse," or "blasting fuse." A fuse with a PETN or other high explosive core is called "detonating cord" or "primacord."

FUSE, BICKFORD. A safety fuse, having a core of black powder enclosed within a tube of woven threads, surrounded by various layers of textile, waterproof material and sheathing. Burns at specific rates.

FUSEE. (pronounced "fu-zee"; not to be confused with FUSEE (rocket, French)). 1. An igniter squib for a rocket motor. 2. A pyrotechnic signal, used as a safety signal on railroads, normally consisting of a tube or cartridge with a spike point base. When placed in an erect position and ignited, the cartridge burns with a white or colored light for a definite period of time. Example: FUSEE, WARNING, RAILROAD: red, 5-min.; FUSEE, WARNING, RAILROAD: red, 15-min.

FUZE. 1. A device with explosive or pyrotechnic components designed to initiate a train of fire or detonation in ammunition. Types of fuzes are distinguished by modifying terms forming part of the item name. 2. To equip an item of ammunition with a fuze.

GAS. An obsolete term for chemical agent. The preferred terms are casualty agent, toxic chemical agent, or riot control agent.

GRANULATION. Size and shape of grains of pyrotechnic ingredients. See GRIST.

GRAYBODY. A temperature radiator whose spectral emissivity is less than that of a blackbody. The spectral emissivity of a graybody remains constant through the spectrum.

GRENADE. A small explosive or chemical missile, originally designed to be thrown by hand, but now also designed to be projected from special grenade launchers, usually fitted to rifles or carbines. Grenades may be classified in a broad sense as hand and rifle. Many varieties and variations of these have been used, including a number of improvised ones. Some of the principal types and designations used in recent years are identified by the following. Chemical grenade is a general term for any hand or rifle grenade charged with a smoke of other chemical agent. Burning type chemical grenade is any hand or rifle grenade that releases its chemical by a burning action. A bursting type chemical grenade is a general term-for any hand or rifle grenade that releases its chemical by a bursting action. Illuminating grenade is a hand or rifle grenade designed to provide illumination by burning. It may be used also as a trip flare or as an incendiary device. Incendiary grenade is a hand grenade filled with incendiary materials such as thermite, and used primarily to start fires. Practice grenade is a hand or rifle grenade used for practice purposes. Riot grenade is a hand grenade of plastic or other nonfragmenting material, containing a charge of riot control agent and a detonating fuze with short delay. The agent is released by a bursting action. Smoke grenade is a grenade containing a smokeproducing mixture. Used for screening or signaling. White phosphorus grenade is a hand or rifle grenade containing a main charge of white phosphorus and a small explosive burster charge for scattering the main charge. Used for smoke and some incendiary effect.

GRIST. Particle size of pyrotechnic material. See GRANULATION.

GROUND SIGNAL. A pyrotechnic signal fired from ground level.

HAND HELD. A rocket propelled, stabilized signal that has the launching mechanism integral with the signal.

HANGFIRE. A brief undesired delay in the functioning of an ammunition item. Usually refers to delay in ignition of a propelling charge. See MISFIRE.

HERMETIC SEAL. A seal made impervious to air and fluids.

HIGH EXPLOSIVE. An explosive that when used in its normal manner detonates, rather than deflagrates or burns; that is, the rate of advance of the reaction zone into the unreacted material exceeds the velocity of sound in the unreacted material. High explosives are divided into two classes: primary high explosives, and secondary high explosives, according to their sensitivity to heat and shock. (NOTE: This division is not accepted by some authorities who maintain that high explosives and primary explosives are entirely separate entities.) Whether an explosive reacts as a high explosive or as a low explosive depends on the manner in which it is initiated and confined. For example, a double base propellant when initiated in the usual manner is a low explosive. However, this material can be made to detonate if the propellant is initiated by an intense shock. Conversely, a high explosive such as **TNT,** under certain conditions, can be ignited by flame and will burn without detonating. See LOW EXPLOSIVE.

HYGROSCOPICITY. The tendency of a substance to absorb moisture from its surroundings; specifically the absorption of water vapor from the atmosphere.

IGLOO. A. storage house for explosives. See BEE HIVE, DOG HOUSE.

IGNITER. A readily initiated pyrotechnic composition that is used to function the main charge. See FIRST FIRE; STARTING MIX.

IGNITER TRAIN. Step-by-step arrangement of charges in pyrotechnic munitions by which the initial fire from the primer is transmitted and intensified until it reaches and sets off the main charge. Also called "burning train." Explosive munitions use a similar series, called an "explosive train." See EXPLOSIVE TRAIN.

IGNITIBILITY. Statement of the ease with which the burning of a substance may be initiated.

ILLUMINANT COMPOSITION. A mixture of materials used in the candle of a pyrotechnic device to produce a high intensity light as its principal function. Materials used include a fuel (reducing agent), an oxidizing agent, and a binder, plus a color intensifier and waterproofing agent. The mixture is loaded under pressure in a container to form the illuminant charge.

ILLUMINATING. Indicates, in the case of pyrotechnic ammunition, that the munition is intended primarily for illuminating purposes. Usually contains a flare and may contain a parachute for suspension in the air.

ILLUMINATION. Illumination is the density of the luminous flux on a surface; it is the quotient of the flux **(F)** divided by the area **(A)** of the surface when the latter is uniformly illuminated. $E = dF/dA$. The term illumination is also commonly used in a qualitative or general sense to designate the act of illuminating or the state of being illuminated. Usually the context indicates which meaning **is** intended, but it is desirable to use the expression amount of illumination to indicate that the quantitative is intended.

INCENDIARY. 1. To cause or to design to cause fires. 2. In nomenclature it designates a highly exothermic composition or material that is primarily used to start fires or render equipment unusable by heat action.

INCREMENT. The amount of pyrotechnic composition added to the charge during the process of loading.

INERT. Descriptive of condition of a munition, or component thereof, that contains no explosive, pyrotechnic, or chemical agent.

INITIATION. 1. As applied to an explosive item, the beginning of the deflagration or detonation of the explosive. 2. The first action in a fuze that occurs as a direct result of the action of the functioning medium. 3. In a time fuze, the starting of the action that is terminated in the functioning of the fuzed munition.

INITIATOR. A device used as the first element of an explosive train, such as a detonator or squib, which, upon receipt of the proper mechanical or electrical impulse, produces a burning or detonating action. It generally contains a small quantity of a sensitive explosive.

INTERNATIONAL CANDLE. An international unit of luminous intensity that is the light emitted by five square millimeters of platinum at solidification temperature.

IR WINDOWS. Frequencies of electromagnetic radiation that have the least attenuation by the atmosphere. Important attenuators of IR radiation are water vapor and carbon dioxide. In upper atmospheres, minor gas constituents such as N_2O, O, CO become more important than water. Important windows exist for wavelengths between 3.6 to 4.7 micron wavelength and 8 to 13 micron wavelength.

IRRITANT GAS. An obsolete term for a riot control agent or a lachrymator.

ISOBARIC ADIABATIC--FLAME TEMPERATURE. Adiabatic flame temperature attained in a constant pressure system.

ISOCHORIC ADIABATIC--FLAME TEMPERATURE. Adiabatic flame temperature attained in a constant volume system.

LACHRYMATOR. A chemical that irritates the eyes and produces tearing. Commonly called tear gas. Also spelled lacrimator.

LEAD, EXPLOSIVE. (Rhymes with feed). An explosive train component that transmits the detonation from one explosive component to a succeeding component, as from detonator to booster charge. Also called "explosive lead." See EXPLOSIVE TRAIN.

LEAKER. 1. Term for bomb projectile or pyrotechnic item filled with a chemical agent or composition that is leaking the contents, and contaminating the surrounding area. 2. An item that permits vapors or liquids to enter or leave because of improper sealing.

LINEAR BURNING RATE. The distance normal to any burning surface of the pyrotechnic column burned through in unit time':

LOADING DIE. A heavy walled metallic cylinder employed to confine a charge or pyrotechnic component during consolidation.

LOW EXPLOSIVE. (LE) An explosive that when used in its normal manner deflagrates or burns rather than detonates; that is, the rate of advance of the reaction zone into the unreacted material is less than the velocity of sound in the unreacted material. Low explosives include propellants, certain primer mixtures, black powder, photoflash powders, and delay compositions. Whether an explosive reacts as a high explosive or a low explosive depends on the manner in which it is initiated and confined. For example, a double base propellent when initiated in the usual manner is a low explosive. However, this material can be made to detonate if the propellant is initiated by an intense shock. Conversely, a high explosive like TNT, under certain conditions, can be ignited by flame and will burn without detonating. See HIGH EXPLOSIVE.

LOW ORDER BURST. Functioning of a projectile or bomb in which the explosive fails to attain a high order detonation. Usually evidenced by the breaking of the container into a few large fragments instead of a large number of smaller fragments. See DETONATION.

LUMINOUS EFFICIENCY. The luminous efficiency of radiant energy is the ratio of the luminous flux to the radiant flux. Luminous efficiency is usually expressed in lumens per watt of radiant flux. It should not be confused with the term efficiency as applied to a practical source of light, because the latter is based upon the power supplied to the source instead of the radiant flux from the source. For energy radiated at a single wavelength, luminous efficiency is synonymous with luminosity factor. The reciprocal of the luminous efficiency of radiant energy is sometimes called the "mechanical equivalent of light." The value most commonly cited is the minimum "mechanical equivalent," that is, the watts per lumen at the wave length of maximum luminosity. The best experimental value is 0.00154 watt per lumen, corresponding to 650 lumens per watt as the maximum possible efficiency of a source of light. When expressed in terms of the new value of the lumen these numerical values become, respectively 0.001511 watt per (new) lumen and 660 (new) lumen per watt.

LUMINOUS INTENSITY. $I_j = dF/d\omega$: Luminous intensity, of a source of light, in a given direction, is the luminous flux on a small surface normal to that direction, divided by the solid angle (in steradians) the surface subtends at the source of light.

MACH NUMBER. (M) The ratio of the velocity of a body to that of sound in the medium being considered. At sea level, at the standard atmosphere, a body moving in air at a Mach number of one (M = 1) has a velocity of 1116.2 ft./sec. (the speed of sound in air under those conditions). Frequently shortened to "Mach."

MARKER. A pyrotechnic item used to point out a location on land or water. Frequently contains a dye or a burning mixture for marking a location.

MEAL POWDER. *An* unglazed black powder of very fine granulation. See BLACK POWDER.

MELT LOADING. Process of melting solids, explosives, dyes, and powders into projectiles and the like, to solidify. See CASTING.

MINE. *An* encased explosive or chemical charge placed in position. It detonates when its target touches or moves near it or when touched off by remote control. Two general types are land mines and underwater mines.

MISFIRE. Failure of a round of ammunition to fire after initiating action is taken. See HANGFIRE.

MIXTURE. See COMPOSITION, PYROTECHNIC.

MUZZLE BURST. Explosion of a projectile at the muzzle of a weapon, or at a very short distance from the muzzle.

MUZZLE FLASH. Flame at the muzzle of a gun after the projectile leaves the barrel. Commonly caused by ignition of propellant gases. Also can be heightened by ignition of broken or insufficiently consolidated propellant composition.

MUZZLE VELOCITY. The linear rate of motion of an object as it is expelled from a gun barrel or similar device.

NAPALM. Aluminum soap in powder form, used to gelatinize oil or gasoline for use in bombs or flame throwers.

NONHYGROSCOPIC. Does not absorb moisture from the air. Used frequently when referring to pyrotechnic ingredients.

NOSE. The foremost point or section of a bomb, missile, or the like. Indicates, in fuze nomenclature, that the fuze is to be attached to the nose of the munition for which it is intended; and, in the case of the component of a fuze, that the component is to be used with a nose fuze.

OBTURATE. To stop or close an opening so as to prevent escape of gas or vapor. To seal as in delay elements.

OGIVE. A curved or front section of a projectile or signal.

OXIDIZER. In an explosive or other chemical mixture, a substance that furnishes the reactant for burning the fuel, usually oxygen.

OXYGEN BALANCE. Ratio of self-contained oxygen to fuel in propellants, explosives, and pyrotechnics. Gives the extent that an explosive is deficient or overly rich in oxygen compared to the amount required for complete combustion.

PELLET. A consolidated cylindrical charge.

PELLETING. Process of consolidating cylindrical charges.

PHOTOFLASH COMPOSITION. A pyrotechnic charge that when loaded in a suitable casing and ignited, will produce a light of sufficient intensity and duration for photographic purposes. See CHARGE, FLASH.

PISTOL, PYROTECHNIC. A single shot device designed specifically for projecting pyrotechnic signals. This item may or may not be provided with a method of mounting to an adapter.

PISTOL, VERY. Former terminology for Pyrotechnic Pistol.

PREMATURE: A type of functioning in which a munition functions before the expected time of circumstance.

PRIMACORD. A trade name for a type of detonating cord that consists of a flexible fabric tube containing a filler of high-explosive PETN (pentaerythrotetranitrate). Used to transmit a detonation from a detonator to a booster or bursting charge. Sometimes used by itself to fell trees, dig ditches, and to demolish structures.

PRIMING COMPOSITION. A physical mixture of materials that is very sensitive to impact or percussion and, when so exploded, undergoes very rapid autocombustion. The products of such an explosion are hot gases and incandescent solid particles. Priming compositions are used for the ignition of primary high explosives, black powder igniter charges, propellants in small arms ammunition, and so on.

PRIMER. A relatively small and sensitive device used to initiate the functioning of an explosive, igniter train, or pyrotechnic charge; it may be actuated by friction, percussion, heat, pressure, or electricity.

PROGRESSIVE BURNING. Propellant granulation in which the surface area of the grain increases during burning. Sometimes called "progressive granulation." See DEGRESSIVE BURNING.

PROJECTILE. 1. A body projected by exterior force and continuing in motion by its own inertia. 2. A missile used in any type of gun. Sometimes applied to rockets and guided missiles although these do not fall within the stated definition. "Projectile" is preferred over "shot" or "shell."

PROJECTILE, COLORED MARKER. Projectile loaded with a charge consisting primarily of organic dye, and provided with a burster or bare ejection charge.

PROPELLANT. An explosive material whose rate of combustion is low enough, and its other properties suitable, to permit its use as a propelling charge. A propellant may be either solid or liquid. A single base propellant composition consists primarily of a matrix of nitrocellulose. A double base propellant composition contains nitrocellulose and nitroglycerine. A composite propellant composition contains an oxidizing agent in a matrix of binder.

PUNK, STICK. A preformed material in cylindrical form, which when ignited smolders without flame. Used for igniting safety fuse.

PYROPHORIC. Materials that will ignite spontaneously.

PYROTECHNIC CODE. Significant arrangement of the various colors and arrangements of signal lights or signal smokes used for communication between units or between ground and air.

PYROTECHNIC COMPOSITION. A mixture of materials consisting essentially of an oxidizing agent (oxidant) and a reducing agent (fuel). It is capable of producing an explosive selfsustaining reaction when heated to its ignition temperature.

PYROTECHNIC ITEMS. Devices used to produce sound, colored lights or smokes for signaling, a bright light for illumination, and time delays.

QUICKMATCH. Fast burning fuse made from a cord impregnated with black powder.

RAM. A metallic cylindrical piece used to compress or consolidate pyrotechnic charges in a mold or die.

RELAY. An explosive train component that provides the required explosive energy to reliably initiate the next element in the train. Specifically applied to small charges that are initiated by a delay element, and in turn, cause the functioning of a detonator.

SEDIMENTATION. The process of depositing large size particles in particle size analysis.

SELF-DESTROYING. When used in connection with a fuze or a tracer, self-destroying indicates that the projectile, rocket, or missile with which it is used will be destroyed in flight prior to ground impact in case the target is missed. See SELF-DESTRUCTION.

SELF-DESTRUCTION. Indicates projectiles designed to destroy themselves by fuze or tracer action, without outside stimulus, after flight to a range greater than that of the target. Self-destruction (also called self-destroying) features are used in antiaircraft ammunition where impact of unexploded projectiles or missiles would occur in friendly areas. See SHELL DESTROYING TRACER.

SENSITIVITY. Susceptibility of an explosive pyrotechnic component to react to externally applied energy or changes in environment.

SETBACK. 1. The relative rearward movement of component parts in a projectile, missile, or fuze undergoing forward acceleration during launching. These movements, and the setback force that causes them, are often used to arm or cause eventual functioning of the fuze. 2. Short for "setback force."

SHELL DESTROYING TRACER. A tracer, which includes an explosive element beyond the tracer element, that is designed to permit activation of the explosive by the tracer after the projectile has passed the target point but is still high enough to be harmless to ground troops. See SELF-DESTROYING.

SHORT TRACE. A trace that does not burn over the desired length of the trajectory.

SIGNAL. A pyrotechnic end item that produces illumination, smoke, or combination of these effects for identification, location, or warning. An illumination signal is designed to produce a light primarily, usually white, amber, red, or green; a signal flare. A smoke signal is designed to produce smoke; the smokes may be black, white, or various colors. A smoke and illumination signal produces a sign by production of light and smoke. Signals may be designed to be discharged from aircraft, ground positions, surface craft, or submarines.

SIGNAL KIT, ABANDON SHIP. A group of items consisting of a hand projector and pyrotechnic signals in a metal container designed for use with an abandon ship outfit.

SIGNAL KIT, PYROTECHNIC PISTOL. A group of items consisting of pyrotechnic pistol(s), pyrotechnic signals, and associated items in a container. See also: SIGNAL KIT, ABANDON SHIP.

SIGNAL LIGHT. General term indicating a signal, illumination or any pyrotechnic light used as a sign.

SIGNAL PISTOL. A single shot pistol designed to project pyrotechnic signals. See PISTOL, PYROTECHNIC.

SIGNAL ROCKET. A rocket that gives off some characteristic color or display that has a meaning according to an established code. It is usually fired from a signal pistol or a ground signal projector.

SIMULATOR. A pyrotechnic device used to simulate the effects of various military items for training purposes or decoys. Simulators have been devised for the following: booby traps, artillery flash, hand grenades, air and ground burst projectiles.

SMOKE. A particulate of solid or liquid particles of low vapor pressure that settles out slowly under gravity. In general, smoke particles range downward from about 5 micron diameter to less than 0.1 micron diameter.

Smokes are used militarily for signaling and screening. A signaling smoke is used for communication purposes and is based upon the volatilization of a dye, which upon condensing forms a colored cloud. The dye may be volatilized by detonation of a burster charge, as in a colored marker projectile, or by combustion of a pyrotechnic composition mixed with the dye, as in colored smoke grenades. A screening smoke is used to prevent observation of a particular area. It is primarily produced by volatilization of oil, by white phosphorus, or by metallic chlorides such as zinc chloride, which effectively scatter light. The cloud produced is called a smoke screen. There are three types of smoke screens: 1. A smoke blanket is used over friendly areas to hinder aerial observation and precision bombing. Smoke blankets are formed by smoke generators, mechanical generators used to volatilize oil, and smoke pots, which produce smoke by the combustion of a pyrotechnic composition. 2. Smoke haze is used mainly to conceal activities from observation and ground fire. Formed in much the same manner as smoke blankets. A haze is usually less dense than a blanket. 3. Smoke curtain is a dense vertical development used to restrict ground observation. May be produced by artillery weapons.

SPECTRAL EMISSIVITY. The spectral emissivity of a radiator at any given wavelength is the ratio of its radiant flux density to that of a blackbody at the same temperature and under similar circumstances. Except for luminescent materials, the emissivity can never be greater than one. See EMISSIVITY.

SPECTRUM. The entire range of electromagnetic radiation from the longest radio waves to the shortest cosmic rays and including all visible light.

SPOTTER TRACER. A subcaliber projectile used for fire control with a trajectory that closely matches the trajectory of a larger round. The point of impact is indicated by the terminal spotter explosion, which produces a display of flash, smoke, or flash and smoke. The path of the trajectory is indicated by the tracer and thus aids in directing the fire of a large caliber weapon.

SPOTTING CHARGE. A small charge, usually of black powder in a practice bomb, practice mine, or the like, to show the location of its point of impact. Also, occasionally, used in service ammunition. Also, the pyrotechnic composition used in spotter projectiles for terminal display. Example: CHARGE, SPOTTING, BOMB: M1A1 (for practice bomb, 100 lb, M38A2) (black powder.); CHARGE, SPOTTING, BOMB: MK4 Mod 3; CHARGE, SPOTTING, BOMB: MK7 Mod O; CHARGE, SPOTTING, MINE: practice, M8.

SQUIB. 1. Used in a general sense to mean any of various small size pyrotechnic or explosive devices. 2. Specifically, a small explosive device, similar in appearance to a detonator, but loaded with low explosive, so that its output is primarily heat (flash). Usually electrically initiated, and provided to initiate action of pyrotechnic devices and rocket propellants. An electric squib is a tube containing a flammable material and a small charge of powder compressed around a fine resistance wire connected to electrical leads or terminal. A squib is designed to electrically fire a burning type munition.

STABILITY. Ability of explosive or pyrotechnic materials to withstand long storage under service conditions.

STABILITY TEST. Accelerated test to determine the probable suitability of a pyrotechnic charge for long term storage under a variety of environmental conditions.

STAR. An aerial pyrotechnic signal of short duration that burns as a single colored light. Colors are usually white, amber, red, and green.

STARTING MIX. An easily ignited mixture that transmits flame from an initiating device to a less readily ignitible composition. See FIRST FIRE; IGNITER.

SURVEILLANCE. Observation, inspection investigation, test, study, and classification of pyrotechnic and explosive items in movement, storage, and use with respect to degree of serviceability and rate of deterioration.

THERMITE. An incendiary composition consisting of 2.75 parts black iron oxide (ferrosoferric oxide) and 1.0 part granular aluminum. Thermate (TH2 or TH3) is an incendiary mixture: TH3 contains thermite, barium nitrate, and sulfur; TH2 does not contain sulfur.

TOTAL EMISSIVITY. The total emissivity of a radiator is the ratio of its radiant flux density (radiancy) to that of a blackbody at the same temperature. See also EMISSIVITY; SPECTRAL EMISSIVITY.

TRACER. 1. A tracer bullet used primarily as an aid for directing the fire of a weapon and locating the target. 2. A tracer element for any projectile. 3. As part of ammunition nomenclature, indieates item is equipped with a tracer. A guided missile tracer is a pyrotechnic tracer that provides a sign to permit tracking of a guided missile. A tracer mixture is a pyrotechnic composition used for loading tracers. Also called "tracer composition."

VISIBILITY. The relative clearness with which objects stand out from their surroundings under good seeing conditions. Also called visual range. In meteorology "the visibility" means a distance--that distance at which it is just possible to distinguish a dark object against the horizon.

WARHEAD. (Rocket and Guided Missile) The portion of a rocket or guided missile containing the load that the vehicle is to deliver. It may be empty or contain high explosives, chemicals, instruments, or inert materials. It may include a booster, fuze(s), adaption kit, or burster. Excludes items that contain atomic weapon components.

WHISTLE. A pyrotechnic device that produces a whistling sound on combustion.

WINDOW. 1. IR window. 2. A type of confusion reflector, consisting of metal foil ribbon, but sometimes metalized only on one side. Also known as "chaff." Similar to, but shorter in length than "rope." May be dropped from planes or shot into the air in projectiles. Original use of the word "window" appears to have been strictly a matter of code.

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